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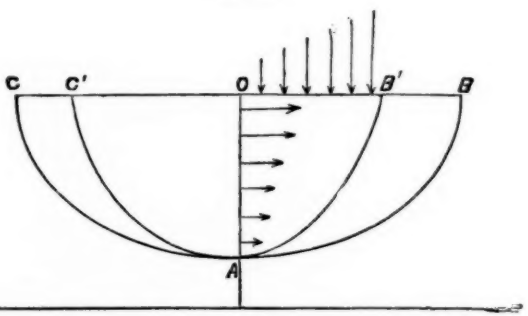
THEORY OF ARCHES.

(*Continued from page 200.*)

Case VII.—If we construct a curve from the last one by using the same ordinates and by changing all the abscissas in the ratio $c:1$, so that the new co-ordinates of a point shall be y and cx, and at the same time change the *horizontal* forces in the same proportion, leaving the *vertical* ones unchanged; the new curve and new system of forces so obtained will evidently be parallel projections of the former, and will be balanced. This new curve C′ A B′ (Fig. 28) is the "Geostatic," and bears a relation to the "Hydrostatic" strictly analogous to that between the ellipse and circle.

Fig. 28.



Hence,

$$\left.\begin{array}{l}\text{The total vertical load on A B}' = \text{V}' = \\ \quad \text{V} = \text{pull along cord at B}'. \\ \text{Total horizontal load on A B}' = \text{H}' = \\ \quad c\,\text{H} = \text{pull along cord at A}'.\end{array}\right\} \quad (35.)$$

The *intensities* are

$$\left.\begin{array}{l}\text{For } \textit{vertical} \text{ load } p'_y = \dfrac{\text{V}'}{\text{O B}'} = \dfrac{\text{V}}{c\,\text{O B}} = \dfrac{p_y}{c} \\ \text{For horizontal load } p'_x = \dfrac{\text{H}'}{\text{O A}} = \dfrac{c\,\text{H}}{\text{O A}} = c\,p_x\end{array}\right\} \quad (36.)$$

(V H p_x and p_y referring to the hydrostatic curve.)

The load at A and B′ and C′ being altogether *normal* (it is not so at the other points), let ρ'_0 and ρ'_1 be the radii of curvature at A and B′.

Then

$$\text{H}' = p'_y \rho'_0 = \frac{p_y}{c} \rho'_0.$$

In the hydrostatic

$$\text{H} = p_y \rho_0. \quad \therefore\ c\,\text{H} = \text{H}' = c\,p_y \rho_0.$$

$$\therefore\ \frac{p_y}{c} \rho'_0 = c p_y \rho_0$$

$$\rho'_0 = c^2 \rho_0 \quad . \quad . \quad (37.)$$

So

$$V' = p'_x \rho'_1 = c\, p_x \rho'_1 = V.$$

But in the hydrostatic

$$V = p_x \rho_1.$$

$$\therefore p_x \rho_1 = c\, p_x \rho'_1.$$

$$\therefore \rho'_1 = \frac{\rho_1}{c} \quad . \quad . \quad (38.)$$

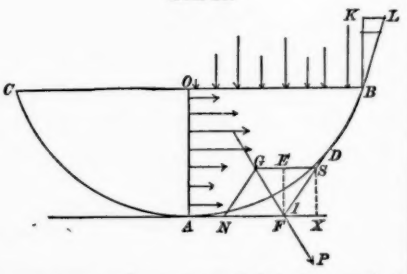
These radii are useful in drawing the geostatic curve.

Case VIII.—So far we have discussed the curves assumed by cords under loads distributed according to some simple law. But it is possible to discuss the more general problem: Given a load that varies and is distributed in any manner, required the curve which it will cause the cord to take; or conversely, given a curve, required the character and distribution of the load to produce it. The most useful form of the problem is that in which we assume the *shape of the cord*, and the *vertical components of the load*, and require to be found the intensity and distribution of the *horizontal components* of the load necessary to produce equilibrium.

To illustrate; assume the curve to be a circle, and the vertical load to be uniform in intensity, we see at once that the horizontal load should be also uniform, and of intensity equal to that of the vertical load.

But generally: Let C A B (Fig. 29) be

FIG. 29.



some assumed curve, and let the vertical load be known in amount and distribution. Making some changes in the signification of the letters heretofore used, now let

V = vertical load on any arc A D.
V_1 = vertical load on the semi-cord A B.
H = horizontal load on any arc A D.
H_1 = " " half-cord A B.
H_0 = pull along cord at A (the quantity heretofore denoted by H).
p_x and p_y = the horizontal and vertical intensities as heretofore.
p_0 = value of p_y at the point A.
ρ_0 and ρ_1 = radii of curvature at A and B.

The vertical load on an arc A D is

$$V = \int_0^x p_y\, dx \quad . \quad . \quad (39.)$$

Again at the horizontal point A, the vertical projection of the element of the curve being = zero, the load is entirely vertical, and consequently at that point is *normal* to the curve. Hence the pull along the cord at A is

$$H_0 = p_0 \rho_0.$$

To discuss the forces upon an arc A D. Draw tangents at A and D. They meet at F (Fig. 29), through which point the resultant of the total load on A D must pass. The *vertical load* is also = the vertical component of the pull along the cord at D, for these two forces, being the only vertical ones connected with A D, must needs balance each other. Therefore,

Lay off F N = H_0. Lay off F E vertical and $= \int_0^x p_y\, dx$. Complete the rectangle F E S X. The pull along the cord at

$$D = F S = F E \operatorname{cosec} i = V \operatorname{cosec} i \quad . \quad . \quad (40)$$

Also,

$$S E = F X = V \cot i = \text{horizontal compound of pull along the cord at D} \quad . \quad . \quad (41)$$

But the horizontal pull at A is

$$H_0 = F N = G S.$$

$$\therefore G E = H_0 - V \cot i = H = \text{resultant of horizontal load on A D} \quad . \quad . \quad (42.)$$

The *intensity* of this horizontal load may be expressed thus

$$p_x = \frac{d H}{d y} = -\frac{\delta (V \cot i)}{d y} = -\frac{\delta \left(V \frac{d x}{d y} \right)}{d y} \quad (43.)$$

At B the vertical load = V_1. Let this be represented by B K (Fig. 29). If the cord be itself vertical at that point, B K = V_1 will be equal to the pull along it at B. If the cord is inclined as in the figure, draw its tangent at B, and

$$B L = B K \operatorname{cosec} i_1 = V_1 \operatorname{cosec} i_1 = \text{pull along the cord.}$$

and

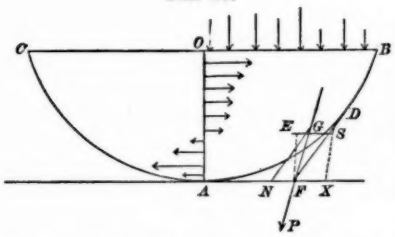
$$K L = B K \cot i_1 = V_1 \cot i_1 = \text{horizontal component of this pull.}$$

$$H_0 - V_1 \cot i_1 = H_1 = \text{resultant of entire horizontal load on A B.}$$

It may often happen that S E = V cot i = horizontal component of the pull along the cord at D (Fig. 30) is *greater* than G S = F N = H_0 = horizontal pull along the cord at A. In such cases G E = $H_0 - V$

cot i is negative, which indicates that the horizontal load between A and D, for at least a part of this distance, must be contrary in direction to that heretofore discussed; that it must exert an *inward pull* instead of an *outward one* (Fig. 30). If

FIG. 30.

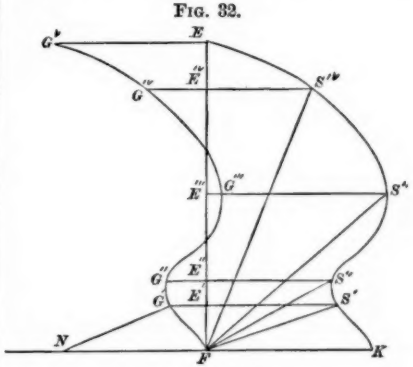


this "inward pull" were removed or replaced by an outward one, the curve would evidently be *flattened* about A.

We may illustrate geometrically, the relation between the forces in all parts of A B.

The vertical load and curve being given draw F E^V (Fig. 32) = the total vertical

FIG. 32.

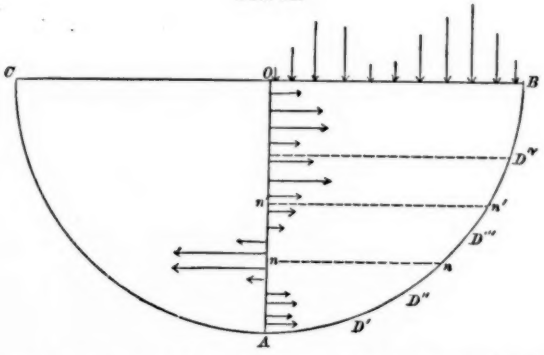


load on A B, and lay off on it

F E′ = vertical load on the arc A D′.
F E″ = " " " A D″, etc.

Draw a horizontal line at F and lay off

FIG. 31.



F N and F K, each = H_o = pull at A. Draw through F lines parallel to the tangents at D′ D″ D‴, etc., and through E′ E″ E‴, etc., lines parallel to the horizon. Then the oblique lines F S′, F S″, etc., represent the pulls along the cord at D′ D″, etc., while E′ S′, E″ S″, etc., represent the horizontal components of these pulls. Lay off from each point S′ S″, etc., horizontal lines, each equal to F N, and draw through the points G′ G″, etc., thus obtained, a curve. It will evidently be similar to that drawn through K S′ S″, etc., and the line G′ E′ will represent the resultant of the horizontal load that must be distributed along the curve from A to D′; G″ E″, the resultant of the horizontal load between A and D″, and so on.

(Fig. 32) is really formed from the parallelogram of forces for the arcs A D′, etc.; this parallelogram being at D′ = F N G′ S′, in which E′ S′ is the horizontal component of the pull at D and E′ G′ = the resultant of the horizontal load on A D′.

As the abscissas of the curve F G′ G″, etc., increase to the left of F E^V from the point F to G′ (which correspond to D″ on the curve), the horizontal load acts outward on the arc A D″. The abscissas then diminish to G‴. Hence between D″ and D‴

on the curve, the horizontal load must act inwards as shown in (Fig. 31). From G''' the abscissas increase until we reach G^{v}. Hence the horizontal load acts outward throughout the remainder of the cord. The points n and n' correspond to those arcs on which the resultant of the horizontal load is zero. Thus on the arc A n the *negative* horizontal load is just equal to the *positive*, and hence their sum = zero. So on the arc A n'.

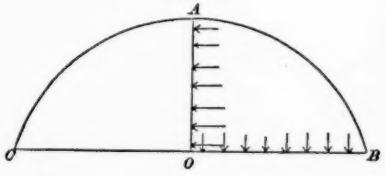
Note that the abscissas of the curve F G' . . . G^{v} are not the *intensities* of the horizontal loading, but that each such abscissa represents the *algebraic sum* of the entire horizontal load between A and the point to which the abscissa corresponds. The *intensity* in question has already been shown to be

$$p_x = \frac{d\,H}{dy}.$$

In this expression $d\,H$ = the difference of two neighboring abscissas of the curve F G' . . .G^{v}; as for instance, $d\,H$ = G' E' − G'' E''. And dy = vertical projection of the arc D' D'' of the cord to which the above corresponds.

ARCHES.

FIG. 33.



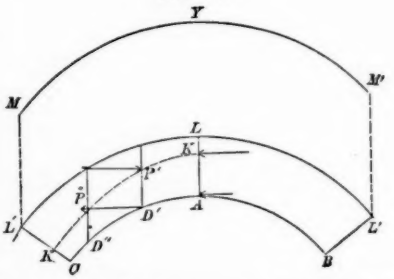
Let us imagine the curve of the cord to be reversed, and the cord itself to be replaced by a thin metal strip, which like the cord shall be practically without transverse stiffness, but, *unlike* the cord, shall be able to resist a compressive force in the direction of its length at every point. Let the loads be distributed as heretofore, except that where there are horizontal components of the load, these should act *inward*, where upon the cord they acted *outward*, and *vice versa*. We then have what is called a "linear arch or rib"; and the curve assumed by it will be identical with that of the cord under equal and similarly distributed loads. If the loading is changed in distribution, the rib will change in shape just as the cord would do under similar circumstances.

In practice there are no "linear arches," but the discussion of them enables us to determine the form of equilibrium for real arches. If we know the form that a *linear arch* would assume under a given load, we can find the "line of pressures" in the real arch. This line and the value of the thrusts at all its points enable us to solve the problems that arise in arch building.

1. Suppose, for instance, we desire to construct an arch to bear a *uniform vertical load*, such as that discussed in *Case I.* The shape of the linear rib under such a load is a parabola. We then as,

1° Step. Assume this curve for the intrados C A B (Fig. 34). If the arch and

FIG. 34.



the load be of homogeneous material, the shape of the *extrados*, or outside of the load, will be M Y M', the vertical distance between C A and M Y being constant.

2° Step. Is to determine the depth A L of the keystone. This depth is always greater than necessary simply to prevent the crushing of the material of the arch under the thrust at the crown. Prof. Rankine's empirical rule derived from the best examples is to make the depth of the keystone in feet

$$\left.\begin{array}{l}\text{In single arches} \\ = \sqrt{.12 \times \text{radius of curva'e at the crown.}} \\ \text{In arches of a series} \\ = \sqrt{.17 \times \text{radius of curva'e at the crown.}}\end{array}\right\} \quad (46.)$$

3° Step. Determine whether the "line of pressures" can lie in the "middle third" of the ring of voussoirs. It should be restricted to the *middle third* to prevent the voussoirs tending to open at any of the joints.

We can test this as follows:

Suppose the voussoirs to be constant in depth all around the arch as in (Fig. 34.) Consider any part of the arch included be-

tween the vertical plane (A L) at the crown, and a vertical plane at any other point, as D′ P′. The calculated horizontal thrust along the linear rib, which coincides in shape with the soffit C A, is indicated by the arrow with its head at A. Let the *horizontal thrust* of the rib at D′ be indicated by the arrow with its head at D′ pointing in an opposite direction to that at A. At the crown take A K not greater than $\frac{2}{3}$ A L. Imagine a left-handed couple applied to A L in the vertical plane of the arch, whose force = H = the thrust at A, and whose lever-arm = A K. Apply an equal and opposite couple on the plane D′ P′, with a force H′, equal to the horizontal thrust of the rib at D′. Its lever-arm D′ P′ must then

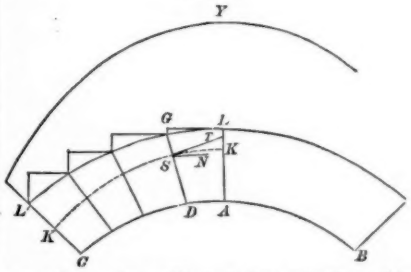
$$= \frac{H \cdot A\,K}{H'}$$

In the parabola H = H′ ∴ D′ P′ = A K. These couples being equal and opposite do not change the conditions of equilibrium of the section of the arch L D′, but they transfer the line in which the thrust acts from A D′ to K P. We can repeat the process as often as we choose by taking parts L D″, etc.; and if the curve drawn through the points K P′ P″, etc., lies within the *middle third* of the arch-ring, the arch is sufficiently stable.

In the case before us, the horizontal thrust being constant for every point of the rib C A, the lever-arms D′ P′, D″ P″, etc., are also equal, and therefore the "line of pressures" K K′ is merely the parabola raised vertically a distance = A K. If K K′ does not lie in the *middle third*, a slight increase in the voussoirs, especially towards the springing, will usually remove the difficulty.

4° Step. The joints between the voussoirs, such as D′ G (Fig. 35) are usually made

Fig. 35.



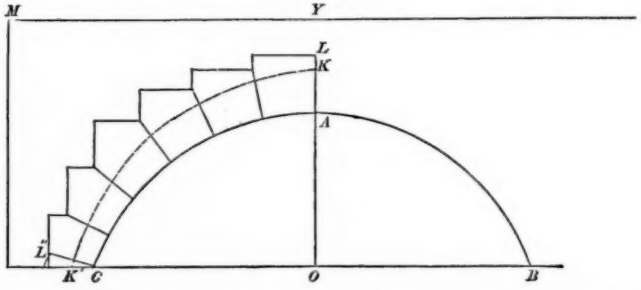
normal to the soffit A C, but whether this be done or not, the direction of G D′ must be such that at S, where the line of pressures cuts it, the angle included between S N (the normal to G D′) and S T (the tangent at S to K K′) may be less than the angle of friction of the material of the voussoirs. The best possible direction for the joints D′ G, etc., would be to make them perpendicular to K K′.

The horizontal component of the thrust (H) along the curve of pressures in a parabolic arch, is, as we have seen, constant; but the thrust along the curve (T) increases from A to C, and its value at any point may be determined by the formulæ in Case I.

Parabolic stone or brick arches are not common, because it is rare to have such a distribution of the load as that supposed above.

2. But if we reverse the curves discussed

Fig. 36.



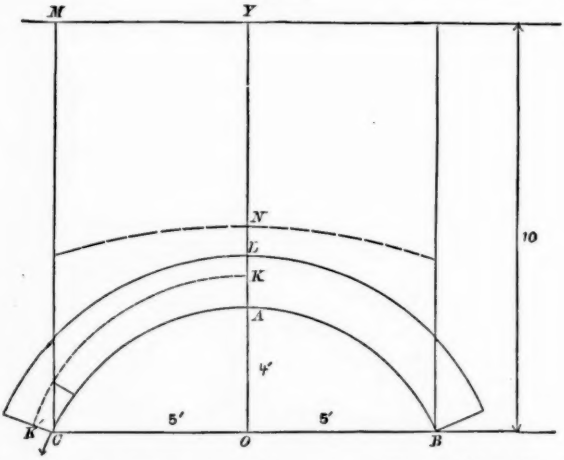
under Cases II. and III., we have a form of arch much more frequently applicable.

Thus, suppose the arch and its backing to be homogeneous, and that the *extrados* of this loading is horizontal (M Y), and suppose the action of the load to be entirely

vertical. Then the arch and its backing are similar to the metal sheet and the cord discussed in the cases just referred to, and therefore the form of the *linear rib* under such a load will be a catenary or transformed catenary—usually the latter.

Assume this curve for the soffit C A B (Fig. 36); determine the depth A L; the line of the pressures K K′; and the direction of the joints; as in the last case. In this case as in the parabola, H is constant and hence the curve of pressures is merely the curve C A raised vertically through a distance = A K.

FIG. 37.



Example. Let the data for a required arch be (Fig. 37) span C B = 10′; rise O A = 4′; height of extrados M Y above springing at C = 10′. Let the arch and brickwork be of solid brickwork whose weight w per cubic foot = 112 lbs.

The equation of the transformed catenary passing this C A B is

$$y = \frac{y_0}{2}\left\{ \mathrm{E}^{\frac{x}{m}} + \mathrm{E}^{-\frac{x}{m}} \right\}$$

Where y_0 = A Y = 6′ (the origin being at Y and the axis of abscissas horizontal).

First find m, the modulus of the corresponding common catenary. By Eq. (14.)

$$m = \frac{x'}{\left\{ \frac{y'}{y_0} + \sqrt{\frac{y'^2}{y_0^2} - 1} \right\}}$$

At the point C x' = 5 ft. and y' = 10 ft.

$$\therefore m = 4.54 \text{ ft.} = \text{Y N.}$$

Then determine points of the curve, thus for

$x = 1$, $y =$ for $x = 2$, $y =$ for $x = 3$, $y =$ for $x = 4$, $y =$ etc.

Describe the curve through these points.

The thrust at the crown A is (for a unit of length of the arch)

$$\mathrm{H} = w\, m^2 \text{ from Eq. (16).}$$

$$\therefore \mathrm{H} = (112)\,(4.54)^2 = 2308.3 \text{ lbs.}$$

From eq. (15) area A Y M C =

$$\frac{m\, y_0}{2}\left\{ \mathrm{E}^{\frac{x}{m}} - \mathrm{E}^{-\frac{x}{m}} \right\} = 36.32 \text{ sq. ft.}$$

Weight of load A Y M C = P = (112) (36.32) = 4067.84 lbs.

From Eq. (18) thrust at C = T = $\sqrt{\mathrm{P}^2 + \mathrm{H}^2}$ = 4677.1 lbs.

Inclination at C. Tan $i_1 = \frac{d\,y_1}{d\,x_1} = \frac{y_0}{2\,m}$

$$\left\{ \mathrm{E}^{\frac{x'}{m}} - \mathrm{E}^{-\frac{x'}{m}} \right\} = 1.77.$$

$$\therefore i_1 = 60° 32'.$$

The formula for depth of keystone will be satisfied by making the depth of the arch A L = length of one brick = 9″ for this gives 9″ × 12″ = 108 square inches to bear the thrust H = 2308.3 lbs., or T = 4677.1 lbs. The latter is the greatest thrust in the arch.

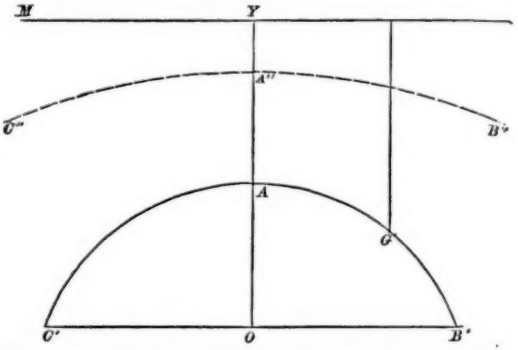
It is easy to see that K K′ will be in the middle third, for even at C the distance of the point of the curve K K′ vertically over C, from the nearest point of C A, is approximately

$$6 \times \cos (90° - 60° 32') = 5'' +.$$

The *extrados* of the transformed catenary need not be the directrix M Y; it *may* be another transformed catenary *provided these catenaries have the same directrix.*

To illustrate: suppose the weight of a unit of the material between C A B and M Y $= w$. Then the intensity of vertical pressure at any point G of C A B (Fig. 38) is $=$

Fig. 38.



$w\,y$. If a heavier building material were used this vertical pressure could be brought upon G by a less height of it. Let this heavier material have a weight per unit $= w'$ and let

$$w' = \frac{2}{3}\,w.$$

Then a column of the heavier material over G and of a height $= \frac{3}{2}\,y$ would give the same pressure as the whole column of the lighter, or

$$w\,y = \frac{3}{2}\,w'\,y \quad . \quad . \quad (47.)$$

At each point of C A B (Fig. 38) lay off two-thirds of the vertical ordinate, and through these points draw C'' A'' B''. The upper surface of the load may have this form, and yet C A B still be the shape of the linear arch balanced under the applied forces. The equation of C A B being

$$y = \frac{y_0}{2}\left\{ \mathrm{E}^{\frac{x}{m}} + \mathrm{E}^{-\frac{x}{m}} \right\}$$

that of C'' A'' B'' is evidently

$$y' = \frac{\frac{1}{3}\,y_0}{2}\left\{ \mathrm{E}^{\frac{x}{m}} + \mathrm{E}^{-\frac{x}{m}} \right\} \qquad (48.)$$

The principle of this example is general.

When the *extrados* is a transformed catenary, note that, since in all the formulæ under Case III., $w =$ the weight corresponding to a unit of surface of the space between C A B and M Y, we must make in these formulæ

$$w = n\,w'$$

Where $w' =$ weight of the building material and $n = \frac{\text{A A''}}{\text{Y A}}$.

In arches of this class no provision is needed for horizontal thrust on the spandrels as the arch is equilibrated under vertical loads alone.

In all stone or brick arches, the changes in the curve of pressures K K′ due to passing loads are usually slight, because the weight of such passing loads is generally small compared with the weight of the arch itself and its backing.

3. The simplest practical case in which a uniform normal load (such as that discussed in Case IV.) can be applied to an arch is when it is subjected to water pressure, the arch ring being horizontal instead of vertical. Such a pressure will exist on an empty well constructed in a reservoir or other body of water (Fig. 39). For each horizontal layer of the well wall may be considered as subjected to a uniform normal pressure of an intensity due to the depth of the water at that layer. This intensity will of course diminish (and so will the pressure on the wall) from one layer to another as we come towards the top.

The soffit of such a well should be *circular* from (Case IV). The thickness of the wall at any depth must be determined by the thrust, which is constant all around any given layer and is

$$T = p\,r = w\,y\,r. \quad . \quad . \quad (49.)$$

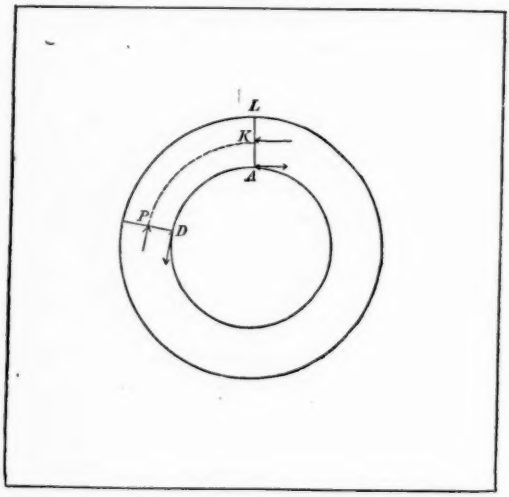
Where $w =$ weight of a unit of water and $y =$ depth of water at the layer in question.

In determining the line of pressures consider a section of the wall between two ver-

tical planes not parallel as heretofore, but both normal to the soffit. Take for the lever-arm of the couple at A (Fig 39) a distance A K = ½ A L. The *force* is still to be = H = T.

At D apply an equal couple with force

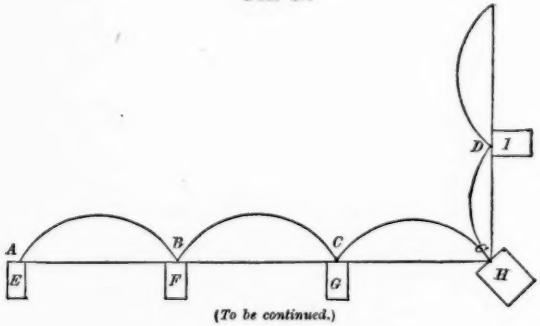
FIG. 39.



= the thrust along the soffit at that point, which is also = T = H. Then the lever arm must be equal to A K. Hence we see that the curve of pressures is a circle *parallel* to the soffit and may pass through the middle of the arch ring.

This kind of arch may be used for dams or the walls of reservoirs. (See Fig. 40.)

FIG. 40.



(To be continued.)

COMPOUND ENGINES.

BY A. MALLET.

Translated for Van Nostrand's Magazine.*

We devote a few pages to the history of Compound Engines; a history heretofore little known; which we are able to make complete by means of documents that enter into minute details, and which contain matter instructive and interesting, while they

* Etude sur les Nouvelles Machines aVapeur Marines. Premiere Partie. Economie de Combustible par Bramwell (Traduction). Deuxieme Partie. Etude sur les Machines Compound, par A. Mallet. Paris, A. Bertrand, Editeur.

shed light upon subjects heretofore obscure.

The idea of employing the expansive power of steam is generally attributed to James Watt. This is shown by the evidence of a patent of Jan. 5, 1769, No. 913. The process consisted in arresting the introduction of steam a little before the termination of the stroke of the piston, thus reducing the pressure at the moment of the reverse stroke; it was not until sometime after that it was perceived that a certain quantity of steam was thus economized.

Jonathan Hornblower, who built the Newcomen engines, patented the use of two cylinders to effect the expansion, on the 13th July, 1781, No. 1298. He said that he employed the steam after its action in the first cylinder in order to employ it in the second expansively.

Here is the original:

"I use two vessels in which the steam is to act, and which in other steam engines are generally called cylinders.

"I employ the steam after it has acted on the first vessel to operate a second time on the other, by permitting it to expand itself, which I do by connecting the vessels together and forming proper channels and apertures, whereby the steam shall occasionally go in and out of the said vessels."

Hornblower's engine met with small success. As it used steam at low pressure it had but a limited expansive power, and the advantages became of no account; rather they became negative on account of the resistances due to the use of two pistons. Besides, he could not use his engine without borrowing most of the parts of Watt's engine, such as the separate condenser, etc. So Hornblower got by means of his invention only the enmity of the friends of Watt, who accused him of indirect plagiarism, and created a bad reputation for him, of which traces are found in the early histories of the steam engine. At this time the use of two cylinders turned out unsuccessful.

But when higher pressure was employed, Woolf did for the engines of Trevithick, Evans, and others, what Hornblower had done for those of Watt; he applied to them the principle of the double cylinder. As he could make use of high pressure, there was promise of success for the invention, and it did succeed, so that he has given his name to engines having two cylinders.

Woolf's patent was taken out in 1804. It contained, as has often been remarked, erroneous notions about the expansive power of steam.

The fact that contributed to the success of Woolf engines, was that although the expansion was not sufficient to yield much advantage over ordinary engines, the division of the work of the steam between the two pistons diminished the differences in pressure and the loss of steam. This was an important matter in the early constructions. Engines of this kind need little repair. We could mention two instances in an industrial centre in Normandy, of engines with two cylinders, which have been in action for nearly fifty years.

In 1805, Willis Earle took out a patent for engines composed of a large and small cylinder superposed, with two pistons mounted on the same rod, a device frequently repeated since that time.

The first Woolf engine was set up in a London brewery. Afterwards Hall made a large number. In 1815 they were introduced into France by Edwards, and they rapidly came into use, without much change in construction. Edwards' engine of 1817 differs hardly at all, even in details, from those that are to-day put up in some of the manufacturing towns. In 1820 the English engineers, Aitken and Steel, built engines with three cylinders, two small and one large. Notice of these engines appears in various works, especially in that of R. Stuart.

In 1824 Joseph Eve patented a compound engine, in which the steam, after acting in a high-pressure engine, passed into a low-pressure engine, where it acted expansively. He employed rotary engines. Here was the first idea of a mode of action different from that of Woolf's engines.

In 1834 Ernest Wolff (a German, we infer, from his name) took out a patent (No. 6,600) of an engine described as compound, as nowadays constructed, which indicates the possibility of modifying existing engines so as to adapt them to the new mode of action.

This patent is very interesting, and it is singular that English authorities hardly refer to it.

It is certain that compound engines with two cylinders and intermediate reservoir, to which the name of Woolf has been given, though they have not the same mode of action, should be called "Wolff engines."

We give the essential part of this patent. "The invention consists of the combination of two or more engines, each complete in all its parts, and so disposed that while the

first receives steam at one, two or more atmospheres of pressure, the next engine is moved by the steam that escapes from the first. In the last engine the steam is condensed in the ordinary way, or escapes into the atmosphere. The work supplied by the several engines is applied to the same shaft, or to several combined, or to independent shafts.

"As in steam vessels and other applications, two conjoined engines are generally employed. The present invention is especially adapted for this purpose, as it presents economic advantages; as it reduces the expense of the apparatus without increasing its complication.

"It is sometimes useful to have between the cylinders an intermediate reservoir to regulate the pressure; this may be placed with advantage at the base of the chimney, so as to maintain or raise the temperature and the pressure of the steam in its passage from one cylinder to the other. Indeed, if necessary, the heat may be supplied by a special fire-box.

"It is often necessary to employ a special pipe with a stopcock to admit the steam from the boiler to an intermediate reservoir in order to give to the machine the power of starting any crank. This direct introduction may be employed to increase for a time the power of the engine."

The writer then explains a method of modifying old engines by adding to a high-pressure engine a low-pressure cylinder; or, in the case of a marine engine, by substituting for one of the low-pressure cylinders a high-pressure cylinder.

The drawing annexed to the patent shows a pair of marine beam-engines.

In 1837, William Gilman patented an engine consisting of two cylinders placed one on the other, one of them having an annular piston with a single cut-off, with multiple ports disconnecting the two cylinders. This disposition has been often reproduced, and is frequently employed nowadays, especially in Sweden. Gilman also describes an engine of three cylinders in which the steam acts in succession.

In 1837, Jonathan Dickson patented (No. 7,439) engines in which the steam acts successively by means of boilers with decreasing pressure, or parts of boilers constituting a compound boiler. This contrivance has also been made use of since the time of the invention. In fact, it is nothing more than Woolf's patent: for this proposes to re-heat the intermediate reservoir by a special fire-box, a process which constitutes in a certain way a low-pressure boiler.

Dickson proposes the use of feed-pumps to serve as guides to the piston cranks, and to control the slide-valves of each engine by the other engine.

In the same year James Slater patented (No. 7,467) engines acting in the same way, with an intermediate reservoir, employing a low-pressure boiler. He describes a regulating valve designed to keep the steam pressure at a fixed point, and also to start the engines. This is nothing more than Woolf's invention—the valve, perhaps, excepted.

The drawings annexed to the patent show various applications, especially a pair of marine beam-engines.

William Whitman, in 1839, patented an engine in which the piston has a sheath on one side only, so that the cylinder has two different capacities. The steam first acts in the annular space, then expands into the other portion of the cylinder. This disposition, applied with some success by the inventor, has been frequently reproduced. It is probably the simplest way of applying the Woolf method of action.

In 1841, James Sims patented an engine of two superposed cylinders, with pistons on the same rod; with this special distinction, that the bottom of the smaller piston is in constant communication with the top of the larger.

In 1842, Hinrik Zander took out a patent (No. 9,516) of an engine, in which the steam acts in the first cylinder expansively, to a certain extent, then passes into two others which are larger, and expands. The three cylinders are attached to the same shaft, so that their motion may be as uniform as possible. The low-pressure cylinders are provided with jackets which contain the steam from the boiler. Zander describes intermediate reservoirs, and proposes to introduce into them, or into a communicating pipe supplying their place, a float-valve to allow the escape of condensed water.

In his drawings is represented a disposition in which the crank of an oscillating high-pressure cylinder, placed obliquely, is attached to the crank of a marine beam engine. This engineer (probably of Holland) seems, according to documents which we have found, to have built some marine engines on this plan.

Octavius Henry Smith patented, in 1844,

an engine acting on the Woolfian principle, consisting of a high-pressure and a low-pressure cylinder, both oscillating and having their rods attached to the same crank. The Cricket Engine, referred to in Bramwell's memoir, is of this kind. A complete description will be found in the "Practical Mechanic and Engineer's Magazine," 1847. Afterwards, we find many patents of expansion engines. We mention only those of Perkins, 1844; McNaught, 1845, which modified old engines by the addition of a high-pressure cylinder; of Thomas Craddock, 1852; Daniel Adamson and Leonard Cooper, 1852, which superheated the steam in its passage from the high to the low-pressure cylinder, by means of tubes set in the smoke-box of a tubular boiler.

We shall not go further in our examination of these patents. It is perceived that, since 1852, all the essential elements of the action of steam by expansion, in separate cylinders, have been pointed out, and that there remains nothing to be invented, even in perfecting details. We shall look further back for applications.

The Cricket Engine was built in 1847, by Joyce & Co., of Greenwich. It exploded the the same year. Bramwell speaks of a boat built at about the same time by Spiller, in which was placed an engine, consisting of a low and high-pressure cylinder. We have found no document concerning it.

According to the authority of "Zeitschrift des Oster Ing. and Arch.," 1867, M. Roetgen of Rotterdam has built engines, since 1840, composed of cylinders inclined towards each other, and acting on the same pair of cranks, the same steam being successively used in the two cylinders. These engines were put into the boats Elizabeth, Stadt Magdeburgh, Kron-Prinz Paul Friedrich.

We do not regard the date 1840 as exact. If, as is probably the case, these engines are those made according to the plans of Zander, they were evidently built after his patent of 1842.

The journal "Engineering" of Sept. 9, 1870, contains a description and drawing of an engine built in 1848 by the Sterkerader Hütte for the Rhine boat Kron-Prinz von Preussen. This engine had two cylinders one $0^m,508$ in diameter, and $0^m,800$ long; the other $0^m,914$ in diameter, and $0^m,914$ in length. Each acted on a crank; the two cranks were connected so that the effect was the same as if the cylinders acted at right angles upon the cranks, while the angle between the axes was 130°. There was no special intermediate reservoir. The connecting-pipe $0^m,254$ in diameter, acted in its stead. There were no steam jackets, and, as no precaution was taken to prevent the condensation of steam in its passage from one cylinder to the other, economical results could not be expected.

Still it is a fact that Feyenoord's works at Rotterdam, where these engines were first constructed, have never given them up. We ourselves saw at Rotterdam in 1860 a steamboat of 70 h. p. nominal, the Wilhelm II., which had served as a pleasure boat for the King of Holland. The engine, with low-pressure cylinder, had been modified by the addition of a high-pressure cylinder inclined to the other, acting on the same crank, the same steam working successively in the cylinders.

It would be unjust to omit mention of Carillon, a Paris builder, who succeeded (1842) in making a low-pressure engine work with the discharged steam of one at high pressure. This was set up at the St. Louis Glass Works. The essay seems not to have been repeated; being abandoned, we think, because of the failure of a surface condenser.

In 1852, James Samuel applied the principle of continuous expansion to locomotive engines. This consists of a simultaneous action of steam upon the two pistons. Suppose two pistons whose rods act at right angles to the crank. The steam works at full pressure during half the stroke of the first. At this moment admission ceases, and the first cylinder is put into communication with the second while its piston is at the beginning of its stroke. Expansion occurs simultaneously in the two cylinders until near the end of the stroke of the first, then in the second, only till nearly the end of its stroke.

This system, related to that of Milner, mentioned in Bramwell's memoir, has been again taken up by Stewart & Nicholson, and applied in the tugs on the Thames. Though simple, it has the disadvantage of not avoiding great depression of temperature as well as those of Woolf & Wolff, since the two cylinders communicate with the discharge ports or the condenser.

The experiments of Samuel, reported in the "Memoirs of the Institution of Me-

chanical Engineers," 1852, were made on a freight and a passenger engine on the Eastern Counties Railway. In the first there were two equal cylinders; in the second the larger cylinder had a section twice as large as that of the smaller. Though the results seemed quite favorable, the essays were abandoned until the time when they were again resumed by Stewart & Nicholson. This is inferior to the other kinds of compound engine.

The first noted applications of double-cylinder engines were made at Glasgow, in 1856, by Randolph & Elder. A little after, Rowan & Horton constructed three cylinder engines; one high-pressure feeding two others. There were 6 cylinders in the machine. The steam was supplied at a pressure of 8 atmospheres by boilers of a special form.

One of these engines, according to Rankine, should not consume more than 0,500 k. of fuel per horse power hourly. This would seem doubtful; but it would be useless to discuss the point, for the engines have not stood the test of service. The boilers are rapidly destroyed, and the construction is too complicated. The condensers were surface condensers of a particular pattern.

Rowan & Horton put one of their engines into L'Actif, a French vessel.

In 1859, Humphreys & Tennant, of Deptford, built for the Peninsular and Oriental Company Woolf engines with moderate tensions. These engines, set up in the steamers Poonah, Mooltan, Carnatic, Baroda, Delhi, etc., at first gave good results. The pressure was 25 lbs., with surface condensation. The cylinders of the Mooltan were 96 and 46 in. in diameter, with a length of 3 ft. Consumption was 2½ lbs. per horse power. The good results were not permanent, especially in matters of detail.

All these have been replaced by single engines built by Humphreys & Tennant.

In 1861, Normand changed to the Wolff the engine of the small steamer Le Furet built by Penn. The engine worked at 6 atmospheres with intermediate reservoir, re-heating, and *monhydric* condensation. The results were excellent. Afterwards Normand altered in the same way the engines of the Eclair, the Albert, etc., and still constructs the same kind of engines

The Imperial Marine made essays moderately successful with three cylinders. The expansion was not great enough, the cylinders being of the same diameter, so that the economic advantage was not important.

But the principle seems natural, and the English Admiralty is at present changing the engines of the ship Jumna.

Escher, Wyss & Co., of Zurich, have built, from the plans of their engineer, Murray Jackson, marine engines with a low and a high-pressure cylinder, set side by side and acting perpendicularly to the cranks. One of these engines was exhibited at Paris in 1861, but it was out of sight under a shed. They have no special intermediate reservoir, the connecting pipe of the cylinders acting in its place. This firm have constructed a large number for the Swiss and Italian lakes, for the Danube, Rhine, and other rivers. Their engines are of the Woolf system. One with four cylinders was exhibited at London in 1862; it is now upon a boat upon Lake Lucerne.

The compound marine Wolff engine is at present built in many English shops; though some maintain the Woolf type, with superposed cylinders. In France all engines are of the first kind.

II. We now consider the method of action in compound engines, beginning with those of Woolf.

In this system the pistons almost always move parallel and in the same direction, although engines with opposing cranks have been constructed (Randolph & Elder; Bondier Frères, of Rouen; Carret, Marshall & Co.) in order to have more direct connection between the cylinders. We suppose that the cylinders have the same length.

The steam acts directly upon the first piston, then expansively; and when the small piston is at the end of its stroke, the connection with the large begins, so that the space under the action of steam at any instant is composed of a fraction of each cylinder, the fractions having an inverse ratio.

We calculate the volume for each period of the stroke, and find the corresponding pressure by Mariotte's law. Let S and s represent the areas of the pistons, l the stroke when the pistons are at a distance z from the beginning of the stroke. The remaining volume in the small cylinder is $s(l-z)$, the volume of steam in the large cylinder is Sz, hence the total volume occupied by the steam is

$$s\,(l-z)+S\,z$$

or

$$s\,l-s\,z+S\,z=s\,l+(S-s)\,z.$$

If P′ is the pressure at the end of the

stroke of the small piston, the pressure at any point between the two pistons is

$$X = \frac{P' s l}{s l + (S-s) z}.$$

By giving to z a number of values, the curve of expansion may be constructed.

P′ is the boiler pressure if there is no expansion in the small cylinder; otherwise, from P′ we deduct P′ from the pressure P in the boiler by the relation

$$P' = P \cdot \frac{l}{l n}.$$

n being the expansion in the first cylinder. Denoting by v and V the volumes of the cylinders, by m the total expansion, we have for the expenditure of steam

$$q = \frac{V}{n}.$$

The work of the volume q of steam is

$$T = q P \left((1 + 2{,}3026 \log. \frac{V}{q} \right)$$

an expression which does not contain v, *i. e.*, the work does not depend on the volume of the small cylinder, but only on the volume q of steam expended, and upon the dimensions of the large cylinder and the initial pressure.

Theoretically, then, the work is the same as if there were no small cylinder, and the volume of steam introduced into it is directly expended in the large cylinder. Should we therefore conclude, as most persons do, that the small piston does no work, and that it is merely a distributor? This would be utterly erroneous; the work of the low-pressure cylinder alone, would be represented by V and by a certain mean pressure π. Then denoting by p the mean pressure in the small cylinder, by p' the mean pressure between the two pistons, we have

$$T = v p - v p' + V p.$$
$$= p v + p' (V - v) = V \pi.$$
$$\therefore \pi = p' + \frac{v}{V} (p - p'),$$

a value always larger than p'; hence the total work is always greater than that of the large cylinder.

From the expression $m = \frac{V}{v} n$ we have $\frac{V}{v} = \frac{m}{n}$, which determines the proportion between the cylinders for a given total expansion and introduction into the first cylinder.

We observe that in order to have $V = v$, or equal cylinders, we must have $n = m$; and the second cylinder would be useless, so that the two cylinders could be practically equal in Woolf's engine. The same is true in the Wolff engine, as will appear.

The following table shows the dimensions of the large cylinder (those of the small being equal to unity) for given total expansions and admissions into the small cylinder:

Admissions to the small cylinder.		0.3.	0.4.	0.5.	0.6.	0.7.	0.8.	0.9.
Total expansion	5....	1.5	2	2.5	3	3.5	4	4.5
	10....	3	4	5	6	7.	8	9
	15....	4.5	6	7 5	9	10.5	12	13.5
	20....	6	8	10.	10	14.	16	18

The ratio 5 is not exceeded in practice; it being better, for large expansions, to increase the expansion for the first cylinder.

We have so far supposed that there was no dead space, a condition never realized. This space is composed of two parts; one, the space between the small piston and the bottom of the cylinder at the end of its stroke and the port of the small cylinder, the other composed of the interior capacity of the small slide valve, of the connecting pipe between the valve boxes (we suppose each cylinder has its special distributor), of the valve box of the large cylinder, of the port of the large cylinder, and finally of the free space between the large piston and the bottom of the cylinder at the end of its stroke.

The first space contains, at the end of the stroke, an amount of steam (P′) of the final tension of the stroke of the small piston; but the second space contains steam of a tension (P″) corresponding to that existing at the end of the stroke of the large piston; and it should be filled with steam of the tension P′.

A communication is established between the two cylinders; the tension diminishes because of the dead space not corresponding to the displacement of the pistons; and the mean pressure on the large piston is considerably diminished.

In the old two-cylinder engines the dead space is considerable, sometimes exceeding one-third the volume of the small cylinder; but it has been diminished by a suitable disposition of slide-valves; and it can be prevented in a certain measure by causing *compression* at the end of the stroke of the large piston.

If the dead space is a fraction $\frac{1}{k}$ of the volume v of the small cylinder, the pressure at the beginning of the stroke of the large piston, instead of being $\frac{1}{k}$ will be $\frac{1}{V + \frac{v}{k}}$. For example, for $k = 3$, it would be

$$\frac{1}{1.33} = 0.75,$$

instead of 1.

If the initial pressure in the large cylinder, instead of P′ is $\frac{P' v}{v + \frac{v}{k}}$, at the end of its stroke, when the volume is $V + \frac{v}{k}$, the final tension will be

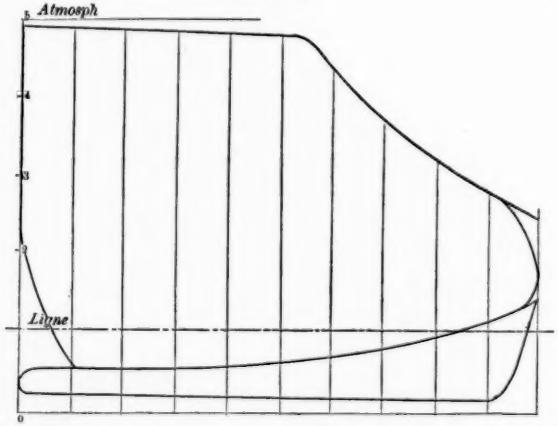
$$\frac{P' v}{v + \frac{v}{k}} + \frac{v + \frac{v}{k}}{V + \frac{v}{k}} = \frac{P' v}{V + \frac{v}{k}}$$

instead of $\frac{P' v}{V}$. The ratio of the two volumes is $\frac{1}{1 + \frac{v}{V k}}$. If $\frac{v}{V} = 0.2$ and $k = 3$, the ratio is 0.98.

The final tension is not sensibly modified because the ratio of the volume of the cylinders diminishes the effect of the dead space; that is, because the steam contained in this dead space expands during the stroke and tends to restore the tension.

For a better understanding of the subject, and to show the action of the engines, we reproduce in Figs. 1 and 2 the diagrams of indicator of a large Woolf beam engine,

FIG. 1.



built by Slawecki, an engineer at Rouen, who subjected the engine to interesting dynamometric experiments.

Fig. 1 shows the curves of the two cylinders to the same scale and with the same atmospheric line. We observe that the counter-pressure of the small cylinder corresponds very exactly to the pressure upon the large piston, showing that the resistances in the passages between the two cylinders are so diminished as to be almost insensible.

That the two curves coincide at one point, is due to the fact that they were taken at the top of the cylinder, where the real representation of the action of the *same* steam upon each piston is not given.

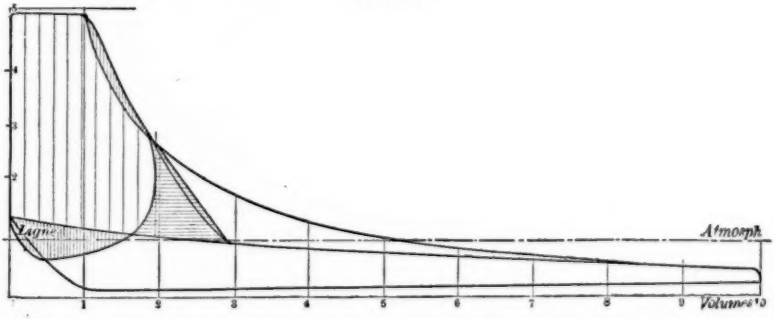
The effect of dead space is shown by the difference between the final pressure in the small cylinder and the initial pressure in the large. In this case the difference is one and a half atmospheres.

In order to compare the action of the Woolf with that of an ordinary engine with a single cylinder, we show in Fig. 2 two curves to the same vertical scale for ordinary pressures, but with abscissas to scales proportional to the volumes of the cylinders. As the two areas coincide upon the portion marked with vertical

hatchings, this portion has been transferred to an equal area hatched horizontally. The curve of work of the steam acting on a single cylinder with the same expansion as in the engine with two cylinders is given; and the small portion of the area corresponding to the work of the small cylinder beyond curve is shown within it.

It is seen that the final pressure is exactly the same in the two systems, except

FIG. 2.



action of expansive engines with one cylinder far surpasses that of the Woolf, a loss in some sort apparent, and depending upon a simply geometric cause.

This would be the place to examine the causes of the superiority of this engine due to expansion; but as this superiority is common, in theory at least, to all double-cylinder engines, we shall consider the question after an examination of the second kind of engines.

We close with this remark concerning Woolf engines: if each cylinder is provided with a special distribution, it is not necessary that there should be a mathematical correspondence of exhaust port of the first cylinder with the admission port of the second. The existence of dead spaces permits separation by a certain interval; while near the dead-points the angular displacement of the crank corresponds to a very small linear displacement of the piston. Hence if each cylinder acts upon a special crank, the two cranks may be set at an angle of 45 deg. to 135 deg., acccording as the pistons are to move in the same or opposite directions. This disposition which facilitates the passage of the dead-points is sometimes employed, as appears in Bramwell's memoir.

III. In the second system of engines, which should be called Wolff engines, the second cylinder is not supplied directly by the first, but by an intermediate reservoir of such dimensions that the pressure within it may be regarded as nearly constant, being in some sort an engine with graduated pressure.

that there is a defect of area of work in Woolf's engine corresponding to the loss due to dead space. Calculating the area of this portion, we find the loss due to the use of two cylinders to be nearly 15 per cent.

The majority of authorities rest here, and take this result as a text for condemning the compound-engine, at least in principle. We shall see that the *physical* loss in the

Denoting by P the pressure in the boiler, supposed equal to pressure upon entering the first cylinder, and by P′ the pressure in the intermediate reservoir, due in the first place to direct introduction of the steam from the boiler, and controlled by a safety valve; by P″ the resisting pressure at the discharge port or at the condenser; then, if the expansion n in the first cylinder is such that the final pressure in this cylinder is P′, or differs from it but little (v being the volume of the small cylinder, and q the volume of the steam admitted), we have

$$\frac{P'}{P} = \frac{q}{v} = \frac{1}{n}.$$

The second cylinder receives all the steam from the boiler at the pressure P′.

Then $\frac{V}{q} = \frac{P}{P'} = m$; m being the total expansion, hence $\frac{V}{v} = \frac{m}{n}$, and the ratio of the volumes of the cylinders is the same as in the first system. But the large cylinder, instead of receiving the steam during the entire stroke, receives it only while a fraction equal to the expansion n' corresponds to the decrease of the pressure from

P′ to P″; $\frac{P'}{P''} = n$ and since $\frac{P}{P'} = n$ and $\frac{P'}{P''} = n'$, $\frac{P}{P''} = n\,n' = m$.

The total expansion is equal to the product of the partial expansions, and the expansion in the second cylinder is equal to the ratio of the volumes of the two cylinders. We see that if one should make the two cylinders equal in an engine of this kind, there would be no expansion in the second cylinder. The engine might act if there were a notable difference between P′ and P″, but the whole possible expansion would not be utilized, and the system would have no *raison d'être.*

One of the advantages of this arrangement is that the dead spaces are not hurtful, as they are actually utilized by enlarging them.

The work of the steam in the first cylinder is

$$T = q \,.\, P\left(1 + e \log \frac{V}{q}\right) - P' v.$$

that in the second is

$$T = q' P' \left(1 + \log \frac{V}{q'}\right) - P'' V.$$

Taking the sum for the total work, and substituting

$$q = \frac{V}{m},\ q' = V\frac{n}{m},\ p' = \frac{P}{n},$$

we have

$$T = \frac{V}{m}\left(P\,(1 + e \log n - 1 + 1 + e \log \frac{m}{n}\right) - P''m),$$

$$T = \frac{V}{m} P\,(1 + e \log m) - P'' m$$

$$= \frac{V}{m} P\,(1 + e \log m) - V\,P''$$

$$= q\,P\left(1 + e \log \frac{V}{q}\right) - V\,P''.$$

This expression represents the work in the large cylinder of the quantity of steam at tension P, expanded from volume q to the volume V.

The principle stated concerning Woolf's engine also holds as to the action of this kind; that is, the work is the same as if the large cylinder were the only one, and the steam admitted to the small cylinder were directly introduced into the large, and expanded in the ratio of the total expansion.

In this kind of engine the work of the two cylinders is regulated as much as possible. Equating the expressions of work given above, we find after proper substitutions

$$v\left(\frac{P(1 + e \log n)}{n} - P_{,}\right) = V\left(\frac{n}{m} P'(1 + e \log \frac{m}{n}\right) - P''),$$

and substituting for P′ its value $\frac{P}{n}$,

$$\frac{V}{v} = \frac{\frac{P\,(1 + e \log n) - P}{n}}{\frac{P}{m}(1 + e \log \frac{m}{n}) - P''} =$$

$$\frac{\frac{P}{n}\, e \log n}{\frac{P}{m}(1 + e \log n') - P''}$$

This expression gives the ratio $\frac{V}{v}$ for known expansions n and n', for we always have $m = n\,n'$.

Remembering that

$$\frac{P}{n} = P' \text{ and } \frac{P}{m} = P''$$

we have

$$\frac{V}{v} = \frac{P'\, e \log n}{P''\, e \log n'} = n' \frac{\log n}{n'}$$

and for $n = n'$

$$\frac{V}{v} = n$$

a relation already known.

In Woolf's engine the extreme difference of temperatures in the small cylinder is larger than in the engine with intermediate reservoir. Here is a theoretic inferiority, at least for engines of slow action in which the decrease of temperature due to the diminution of tension is noteworthy. Hence, as we shall see, the use of an envelope of steam is in this case more necessary.

If the engine with reservoir has a real advantage over that of Woolf, it has, on the other hand, the inconvenience of requiring for considerable expansions, that the admission be early cut off in each cylinder: since for a total expansion of 10 volumes the expansion should occupy $\frac{1}{3}$ in one cylinder, $\frac{1}{3}$ in the other, or $\frac{1}{3.16}$ in each, if expansions in both are equal; and we know that ordinary distribution does not favor small introductions.

Generally a fixed expansion is imposed upon the large cylinder; and the small cylinder is provided with a special apparatus, with variable cut-off to reduce admission as desired. It is difficult, however, to effect large expansions, and too great expansion in the large cylinder produces some of the disadvantages of the single cylinder. It would be better, in this case, to employ multiple expansions and several successive cylinders, as has often been proposed.

(To be continued.)

THE POLA BASIN, DOCK AND RAILWAYS.*

By HAMILTON E. TOWLE, C. E.

Extract from the Minutes of the Proceedings of the Institution of Civil Engineers (London)

About the time that it became evident that the Austrian Government must eventually abandon the port of Venice as a naval station, the harbor of Pola was selected by a commission of Engineers and naval officers as a suitable one to which to transfer its materiel, and at which future permanent works to complete a capacious arsenal and dockyards should be constructed. Pola is situated directly south of Trieste, on the western coast of the peninsula of Istria, south-west of Fiume, and about 60 miles distant from both those ports. Venice, on the other side of the Adriatic Sea, is 80 miles distant in a north-westerly direction. The harbor of Pola is a circular bay, connected by a narrow and short outlet with the Adriatic. It is particularly favorable for the purposes of a naval station, having ample room, good anchorage, and complete natural protection.

The Austrian Government abandoned the idea of constructing excavated docks, in consequence of the difficulties experienced in making the necessary cavities in which to build the works, from the percolation of the sea water through fissures in the volcanic rock; and they determined on the American Floating Dock, Basin, and Railway system. The floating dock adopted was that known as the Balance Floating Dock (Gilbert's System); and the basin and railways were in general principle the same as those constructed at the United States Navy Yards at Portsmouth, New Hampshire, and at Pensacola, Florida. These were the first dock basins with railways that had been constructed; they were contracted for in the year 1848, and active operations were commenced a few months later.

The function of a basin for a floating dock is to supply a place in which the dock itself may be grounded, either with a vessel upon it to undergo extensive and prolonged repairs, or to enable the vessel to be hauled out of the floating dock upon the railways; which latter operation is only required in cases where vessels are moved from the dock to land above the sea-level, or the reverse. Another use to which the basin may be put, should occasion require it, is to provide a convenient means of obtaining access to every part of the usually submerged portion of the floating dock itself, either for examination or repair. A basin to fulfil these requirements must be so constructed as to permit the dock, with or without a vessel upon it, to be floated into it, and the entrance passage to be closed by means of gates or caissons. Where the tidal rise and fall are not greater than the entire depth of the water in the basin at high tide, suitable pumping machinery must be erected.

Calculations, based upon the maximum draught, etc., of the floating-dock, determined the depth and requisite area of the basin at Pola. These dimensions were as follows:—

Width inside the enclosing walls...	211 $\frac{86}{100}$ ft.
Length " " "	311 $\frac{89}{100}$ "
Depth from the top of the enclosing walls to the top of the stringers (for receiving the dock when grounded)	17 ft. 1¼ in.
Depth from the level of ordinary high water to the top of the stringers..	13 ft.
Depth from the level of ordinary low water to the top of the stringers..	11 "
At the highest flood tide the depth above the top of the stringers was	14½ "
At the lowest ebb tide the depth above the top of the stringers was	9½ "

The maximum difference in the hydrostatic head, inside and outside the basin, during the progress of the works, was 20 ft.

The Austrian Government preferred that the basin and railways should, if possible, be constructed at an island (called Scoglio d'Olivie) centrally situated in the harbor, and from which several vessels had already been built and launched. Having mainly in view the treacherous and honeycombed character of the rock forming the harbor, it was decided to build a foundation upon the natural bottom of the bay at the place selected. The first operation consisted in a careful survey and contouring of both the upper and the lower surfaces of the mud bottom, the mud resting upon rock below; and to the care taken in this preliminary survey, the Author attributes much of the success in mastering the

* "An Account of the Basin, the Balance Dock, and the Marine Railways, at the Austrian Naval Station at Pola, on the Adriatic." By Hamilton Ela Towle, of New York, U. S. A.

difficulties which arose as the work progressed. The mud varied from 2 ft. to 12 ft. in thickness. As the rock was unfitted for holding, or even for receiving, sheet-piles, except when they might happen to strike a fissure, it was decided not to use the ordinary clay-puddle cofferdam.

It was observed that at Trieste, Fiume, and Pola, as well as at other Austrian ports, wharves and moles had been successfully constructed of a sort of concrete, bearing the name of Santorin béton; and, as these works had been found durable and permanent in exposed situations, it was determined to adopt this material, as it could be obtained at a reasonable cost, while the expense and risk attending the temporary use and final removal of an ordinary dam would be avoided. The largest blocks of Santorin béton were found in the mole at Fiume. They were 25 ft. in vertical depth, and 22 ft. wide at the top, at the level of low water, battering towards the bottom at the rate of 1 in 4 or 1 in 6. They rested upon loose rubble stone, consisting of ordinary quarry rubbish, deposited on a level bed along the line of the mole for a thickness of several feet. The length of these béton blocks was 50 ft.; and they had been thus formed *in situ*. Plank caissons were built on shore, and were securely tied together, and then launched and floated over the spot selected. They were next loaded and sunk upon the previously-prepared bed of rubble, and the béton was deposited within them. When it had become sufficiently indurated, the planking was removed, excepting 21 cross timbers forming ties to the sides of the caisson, which were left embedded in each block, or section of the wall.

After definitely deciding that Santorin béton should form the substructure of the enclosing basin, and at the same time serve the auxiliary purposes of the ordinary cofferdam, it appeared that to excavate a continuous trench for the walls, to allow them to rest upon the clear surface of the rock under the mud, would involve the construction of special machinery for the greatest depths, and, after all, only secure a solid bottom at great expense, which eventually would have to sustain the weight of the walls themselves when finished. A water-tight joint seemed the one thing most required at the junction of the enclosing wall, or dam, with the bottom, for there could be no leakage or percolation through the body of the béton wall, as long as the material was not cracked by unequal settlements or strains. But the Author assumed that accidents would occur, and that they would, if not effectually provided for, prove troublesome and dangerous.

Many cross-sections of walls were considered; but finally it appeared that a wall of a plain rectangular section presented the greatest advantages and the least objections. In calculating the minimum thickness of walls admissible, regard was paid to the fact that the site of the basin was a greasy mud bottom, dipping towards deep water at an angle of from 2 deg. to 10 deg., and therefore rendering a slip of the basin possible. Cracks and fissures were provided against by joints across the walls, at intervals of from 40 ft. to 90 ft., thereby forming weak places, which being selected with respect to the irregularities of the bottom, the rock protuberances and depressions, the thickness of mud, etc., rendered the location of cracks almost a certainty. Experiments were made to ascertain the sustaining power of the mud bottom when subjected to a pressure somewhat greater than would be brought upon it from the walls and their occasional loads; and this was not found to differ much even in places where the mud varied in depth several feet. In the application of this experimental information, the prominent projections and marked depressions in the rock were found to be distant from each other not less than twice the vertical height of the wall, and this distance was assumed as the proper limit for the length of the superimposed béton blocks, as it had been previously ascertained, by experiment, that the strength of Santorin béton was ample to resist transverse fracture, if the blocks did not overhang the point of support for a greater length than their own thickness. Having determined the probable difference in the compression of the mud at the prominent projections and marked depressions, and knowing the distances of these points apart, and the vertical depth of the two blocks above, the size of the crack, or opening, that would take place between them became a known quantity. Now, if the mud above a depression were compressed 12 in. more than the mud at contiguous projections, and the length of each block were three times its depth, it was clear that the opening between the two blocks would be 4 in. at the widest part, and gradually diminish to zero

at the upper surface. It was found, by this method of calculation that no crack would be likely to exceed 6 in. in its widest part, with vertical butt joints between the adjacent blocks of béton, and the ends of the blocks marked the localities where the cracks would certainly be found. To check the passage of water through the wall, and to connect the adjoining ends of contiguous blocks of béton so as to prevent them moving upon each other laterally, a rectangular post, 18 in. by 24 in., was inserted vertically in each of the joints, reaching from the upper surface of the blocks, through the mud, to the rock bottom below. The post projected 12 in. into each block of béton. These posts received the name of "coags," and were made of two sticks of timber, 12 in. by 12 in., squared up and bolted together until the the proper length was obtained. After smoothing off one of the sides, cross planking, 6 in. thick, was well secured by bolts and treenails, and the joints between the timbers and planking were well caulked. The largest coag joint opening was 5½ in., after all apparent settlement ceased, and the "coags" were found to fulfil all their intended purposes.

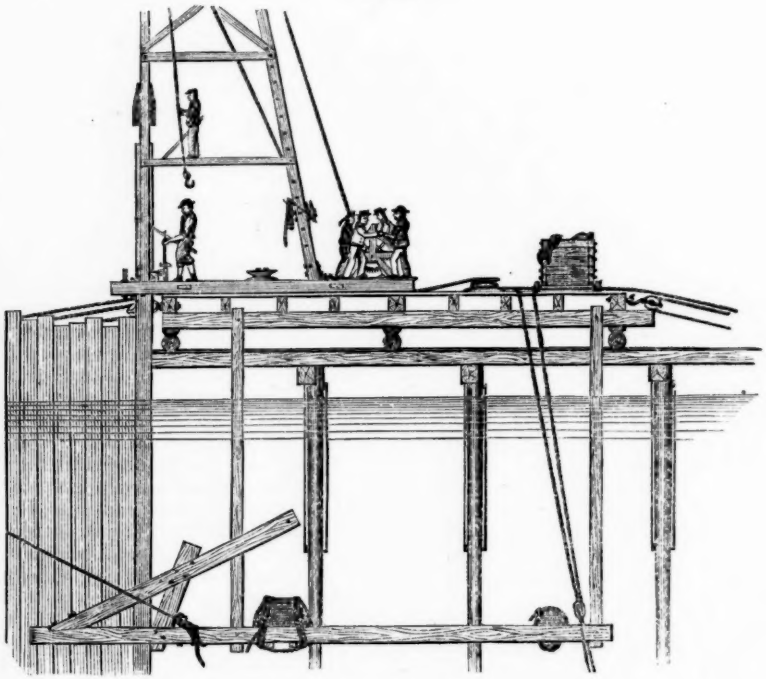
A brief description of the manner of constructing the sheet-piling work or caissons, in which the blocks were formed, will now be given. A few round piles were first driven, by hand and steam pile-driving machines, from suitable floats, to which to secure mooring and hauling lines; then the side walls of the basin were staked out, by driving, 10 ft. apart, two, and in most cases three rows of round piles within the space to be occupied by the Santorin walls. The greatest care was taken to make the stage piles stand vertically, as they were to remain permanently in the walls, as well as parallel to each other, so as to permit the free movement of the béton in settling. Straight, tapering round piles were chosen for this part of the work. Cross caps, of 12 in. sawn timber, were screwed to the heads of the stage piles, and upon them, at their outer ends, longitudinal stringers, 12 in. by 12 in., were securely bolted, the outer sides of which defined the inner and outer faces of the Santorin wall. The staging was strengthened by vertical diagonal bracing, secured to the piles, and by horizontal diagonal bracing secured to the tops of the cross caps. The vertical bracing was removed during the process of filling the caissons, as it was no longer required, the béton affording sufficient support. The greater part of sheet-piling was of soft Italian, Styrian, and Austrian timber, 12 in. thick. Every piece was made quite straight upon the sides adjacent to, or in contact with, contiguous piles, and the piles were driven by ordinary pile-driving machines mounted upon travelling platforms, provided with double-flanged wheels resting upon iron rails, which in turn were supported upon the tops of the longitudinal stringers. To the outer side of these longitudinal stringers the upper ends of the sheet piles were secured as fast as they were driven.

As it was desirable to render the face of the béton wall uniformly smooth, it became a matter of importance to drive the sheet-piling accurately and evenly, a process which the depth of the water, the light specific gravity of the timber, and the character of the bottom, rendered somewhat difficult. To obviate this, the Author devised a machine, which for want of a better term was called a "Spider," and several of them were made and used about the work. It may be described as follows: (See Fig. 1, page 308.)

Two sticks of tapering timber are formed, by sawing a log 35 ft. long and 12 in. square, so that the larger ends are 8 in. by 12 in., and the smaller ends about 4 in. by 12 in. These are placed side by side horizontally, with the larger ends in the same direction, and spaced 12 in. apart, and parallel to each other, to form the side pieces. At about 8 ft. from the thicker ends is fitted a block of solid oak, 30 in. thick and about 6 ft. in length. A width of 9 in. on either side of the lower end of the block is cut away, to leave a thickness of 12 in. in the central part, which is made to project down between the parallel side pieces, and the three are securely bolted together. From its upper end, which is about 5 ft. above the side pieces, the oak piece slopes toward the thicker ends, at an angle with the vertical of 30 deg., and is formed into a sort of throat, to receive the ends of the piles. Two inclined side pieces, or cheeks, of timber, 8 in. by 12 in., and 17 ft. long, are secured, one on each side of the oak throat-piece, near the top, and, running down, rest upon the top of the long tapering side timbers near their thicker ends, to which they are securely bolted, as well as through the throat-piece and through each other. The

side checks and oak block now form a funnel to receive the point of a pile, and to guide it through the 12-in. opening below. Two vertical timbers, called "hangers," 8 in. by 12 in., and about 20 ft. in length, are inserted between the side pieces, in the rear of the oak block, and about 20 ft. apart. They are each hinged at their lower ends, by stout iron bolts passing through both the side pieces and the vertical hangers. The side pieces at the rear are clamped firmly together with a distance piece between them 12 in. thick. Two ordinary tackle blocks, for receiving lateral guys, are now attached to the smaller ends of the side pieces, one on either side, and the guy ropes are rove through the blocks; a 9-in. hawser being made fast to the side pieces near the oak block. The apparatus is next weighted with ballast iron, laid across the side pieces until it will sink promptly, and it is now ready for use. Suppose a few sheet piles to be already driven, and the pile-driving machine to be in proper position to drive another pile in the line, the "Spider" is then advanced so that the two side pieces

Fig. 1.



"SPIDER" FOR FACILITATING THE DRIVING OF PILES IN DEEPWATER.

or horns of the machine are made to pass, one on either side, and clasp the sheet piles already driven; the hawser is drawn taut until the oak throat-block presses hard against the pile last driven, and the lateral side guys, properly secured, are drawn up by the men on the platform, until the machine below is in proper line, which is readily known if the hangers are vertical. All being now adjusted, a sheet pile is raised in the piling machine, and is readily driven in line with those already down. The throat of the "Spider" guides the point and body of the pile to its place, and the elasticity of the hawser permits a pile or two to pass through before slacking. In the result, the control of the work was so perfect, that the sheeting required, at intervals of from 20 ft. to 30 ft., a special wedge-formed pile to be driven butt down, to

keep the work vertical at the driving point. With a "Spider" at least double the quantity of sheet piles can be driven per day in deep water, when the mud is shallow, than is possible at the same expense without such a contrivance, and the work is much better done. Between the surfaces of contiguous sheet piles was a single thread of ordinary spun-yarn ormarlin, which was tacked at each end of the piles before driving. This made the joints almost water-tight, as was proved by the fact that water was often found 2 ft. higher inside than outside the enclosed space.

The sides of the enclosure for one block having been completed, and the "coags" and cross-dams having been put in, the section was bolted together by ties above the level of the béton work. Fifteen of these blocks, or sections, were formed in the entire length of the enclosing walls of the basin, one-half the number being more than 80 ft. in length. At one point the béton wall is 35 ft. high, and the finished wall 7½ (Vienna) ft. higher; making the finished work slightly exceed 42½ ft. in height by 20 ft. in thickness.

The thickness of the walls varied from 15 ft. to 20 ft. and 26 ft. It was decided to make the entrance for admitting the dock on the eastern side of the north end of the basin, and to adapt it for receiving an iron caisson to close it. This opening was 120 ft. wide between the vertical walls, 128 ft. wide at the top line of the caisson, and the caisson measured 122 ft. along the bottom of the keel, each end having a batter of 3 ft. in the entire height of the caisson. The method adopted in constructing the enclosing sheet-piling for the other parts of the work was slightly modified, to meet the requirements of the masonry for the caisson at this point, as well as at the south-west corner, where the pump-well was located.

Santorin béton is composed of Santorin earth—a volcanic product from the Greek island of Santorino—and common lime paste, in the proportion of 7 cubic ft. of the former to 2 cubic ft. of the latter, forming the hydraulic mortar; and to this is added 7 cubic ft. of broken stone of the size usually employed in making concrete. The whole yields a batch containing 9 cubic ft., is made into a conical heap, and tempered by open air exposure for a period varying from one day to three days, when the heaps are ready to be used under water. Block No. 13, for example, required above 2,300 cubic yards, or 6,185 pastoni (heaps) of the prepared béton, and employed 82 men constantly for 18 days to prepare the béton and put it into its place. The cross-dams at the ends of the sections were safely removed in from 2 to 3 weeks after the last béton had been deposited, when the filling of the adjoining section could be commenced. The average time of filling the sections was 2 weeks.

After the bèton walls had been completed, the tie-bolts clamping the sheet piles against the sides of the blocks were gradually loosened, to enable the former to settle freely, and to compress the water from the mud below. Simultaneously, the interior rubble wall was built upon the top of the béton to a level above high water, so as to serve as a dam; and as this was finished, the material required for the superstructure of the walls was piled loosely upon the work already done, to cause the walls to complete their settlement while yet in motion.

The principal internal filling of the basin and the external sloping embankment against the sheet-piling having been proceeded with as the previous work progressed, as well as a temporary clay-puddle cofferdam, closing the intended opening for the iron caisson, pumping machinery was erected, and on the 2d of February, 1859, the operation of emptying the basin was commenced.

In consequence of heavy winds and a maximum rise and fall of the tide, the walls were, during the pumping out of the basin, subjected to a severe test; added to which, the water was removed from the inside of the basin to a greater depth than would occur again in its use. A slight lateral motion of the walls took place along the middle parts of the sides, by the opening of the vertical abutting joints of the sections upon the inner faces of the wall; but only one crack in the béton walls occurred worthy of mention, and this gave considerable trouble for several weeks. It was nearly vertical, and extended entirely through the pump-well wall to the re-entering angle on the outside. It made its appearance during the first twelve hours' pumping, and gradually increased in size until, upon the upper surface of the finished wall, the joints opened 3 in. At the bottom of the wall, upon the inside of the pump-well, there was no visible opening or crack. The separating parts slightly rotated upon

a ridge or ledge of rock directly below, the greater part of the opening being caused by the sinking of the corner against which no supporting embankment had been made. After all the "coag" joints and the pump-well crack had ceased to increase in size, they were carefully cleaned out and walled-up with masonry to the depth of 1 ft. from the face of the wall; and metallic tubes or pipes were inserted through the wall for conveying away any slight leakage that might escape, without washing away the fresh mortar. Where a crack or joint appeared open on the external side of the béton walls, a pad, secured to a plank or timber, was firmly braced against it, until sufficiently tight to prevent the escape of fine mortar or pure hydraulic cement. These openings or fissures were then filled with thin grout, injected through a tube under a head of about 10 ft. above the wall, until the work was solid throughout.

The water having been exhausted from the enclosure to a depth sufficient to lay bare the earthy material previously filled in at the proper level, the work of constructing the bottom of the basin was prosecuted as rapidly as possible. This bottom consisted of thirty rows of foundation piles, capped with timber 1 ft. square, embedded in béton from 6 in. below their lower surfaces to the level of their upper sides. Upon the caps was secured a platform of timber, 6 in. in thickness, upon which was laid the masonry, forming and completing nine lines of stone stringers, to receive the bottom of the dock when grounded. The stringers varied from 8 ft. to 12 ft. in width; and between them the finished bottom of the basin consisted of a floor of Santorin béton, 1 ft. thick, on a layer of broken stone resting on the earth filling below.

The abutments, at either end of the caisson at the entrance of the basin, were built of solid masonry, well tied and bonded together. The floor or apron between the abutments was constructed of stone resting directly upon the béton wall at that part of the work, and when finished resembled in general appearance the entrance to an ordinary stone dock. The masonry superstructure, for the enclosing walls of the basin, consisted of three outside and three inside courses of headers and stretchers, having a uniform rise of 2 ft. 6 in., with a backing of common rubble masonry, the top of which was covered by flagging 9 in. thick. All the cut stone was Istrian marble, obtained from the neighboring islands.

The space of several hundred feet between the southern end of the basin and the island (Scoglio d'Olivie) was filled in with suitable material, and two sets of railways were constructed of a length of about 700 ft. The foundation of the ways was partly of closely-driven piles and partly of masonry resting on the rock below.

The sheet piling upon the outside of the enclosing walls was cut off, by means of a circular saw specially designed for the purpose, at depths varying from 15 ft. to 30 ft. The exposed ends of the piles remained as footings for the walls, and were covered with quarry rubbish to form a uniform embankment round the walls. After this was done, the interstices in the embankment, and the slight opening formed between the footing piles and the wall, were filled with common sand, such as is used for mortar. This was thrown from a float against the outer face of the walls, and found its way into the crevices between the solid material.

Four plain vertical cylindrical pumps of 32 in. diameter, and 36 in. stroke, with their lower ends 22 ft. 6 in. below the finished wall of the basin, were erected as soon as the pump well was sufficiently advanced in construction to receive them. A pair of tubular boilers, 72 in. in diameter, and 24 ft. long, each provided with a pair of furnaces communicating with a combustion chamber, furnished steam to a horizontal engine. This machinery was used for all the pumping during the construction of the basin, and was left for such occasional pumping and other work as might be required.

The caisson for closing the opening to the basin was built by the Messrs. Rennie, of London, and was found to answer its purpose perfectly. On several occasions the basin, after completion, was pumped quite free of water, and found to be almost perfectly water tight in every part.

By the latest accounts, the basin and railways, as well as the floating dock itself, were rendering good and satisfactory service.

Mr. Hemans, Vice-President, said it appeared to him that the dock-wall was in fact an extended permanent cofferdam of great width filled with concrete, instead of a temporary dam filled with clay. He would ask whether the béton was let down into a dry space within the piles, whether

it was dried in the atmosphere before being deposited, or whether it was let down into the water and took its set there? Also, for what reason the walls were made vertical instead of being strengthened by a batter; and further, the time required for the béton to set in the water or out of the water, what was the total cost of the wall, and the manner in which the piles were cut off by the circular saw?

Mr. A. Giles said, that as the dock was only about 300 ft. long, the depth of water about 20 ft., and the rise of tide only from 3 ft. to 5 ft., he thought that to build a solid wall upon a substratum of mud was rather a hazardous way of getting over a difficulty, which would hardly be attempted in England. The ordinary way would be to begin by putting a cofferdam through the mud, to get the mud out, and to build upon the solid bottom. But as the mud was only from 2 ft. to 12 ft. thick, he thought there had been a good deal of unnecessary ingenuity exercised, and it would have been more satisfactory if a temporary cofferdam had been put round what was to have been the basin, and the wall carried up from the solid rock. Under somewhat similar circumstances he had put in a bottom where there was a depth of 30 ft. to 40 ft. of mud to penetrate before the foundation was attained. In doing that he constructed cofferdams in pits of from 6 ft. to 8 ft. square, getting out the mud to the foundation and then throwing in the béton. So long as there was mud under the walls they would be liable to slip and eventually to upset the work. The dock he referred to was 420 ft. long, and the cost did not exceed £63,000. If the outlay for this work for one dock had amounted to £120,000, the cost was heavy.

Mr. Murray said that he thought the béton surrounding wall was not so adequate a means of enclosure as a cofferdam. There could have been no difficulty in obtaining piles of sufficient length and scantling in the locality, inasmuch as they were employed to enclose the béton wall, and if there had been none in obtaining clay he considered it could have been used at a far less cost than the béton. The small thickness of the mud might have been a reason why the cofferdam system was not adopted; but there could have been no difficulty in throwing down clay in the line where the cofferdam was to be formed, and in driving the piles through it, and of obtaining thereby a firm foundation for the piles, even though they struck the rock. He was of opinion that a timber dam filled with clay, and, if none was to be had, even with the mud dredged from the bottom, with probably a little more breadth between the piles than usual, could have been constructed in that locality at far less cost per lineal yard than a béton wall 20 ft. thick. The clay dam, if properly constructed, would have been homogeneous throughout, and no fissures need have occurred, because the bolts might have been fitted with washers hanging loosely in the clay, and they would thus prevent all possibility of leakage.

It might be urged that if the cofferdam had answered the purpose of allowing the water within the enclosure to be pumped out, yet the timber being liable to decay would cause the work in time to become defective, in fact, requiring ultimately a water-tight wall. Now, assuming a cofferdam to have been constructed, it gave the means of permitting débris, or quarry rubbish, to be deposited with a slope on each side of it, which again could have been coated, if necessary, with rubble stones of a larger size to the surface of low water, when either blocks of stone, or artificial blocks of béton, could have been laid upon the deposit and upon the cofferdam carried up to any height and breadth required, thus forming a solid water-tight embankment to the enclosure.

The application of the "spider," for the purpose of driving the sheet piles, was quite new to him. He had often experienced difficulty in driving sheet piles in a considerable depth of water, and had been accustomed to place the main piles 10 or 12 ft. apart, and to connect them with the walings under water by means of divers with helmets or the diving-bell. When these were put on, as well as the upper walings above water, there was no difficulty in driving the sheet piles perfectly tight. But in the plan here adopted the "spider" appeared to him capable of such ready adaptation, that it was scarcely necessary to drive main piles at all, for the sheet piles might be continued one after the other with facility, which was of great importance in driving sheet piles in a considerable depth of water. In cutting off piles with a circular saw under water he had experienced much difficulty by the nipping of the saw; and the detention and trouble arising therefrom had caused him

to abandon it. He preferred the common saw with hand labor from the diving-bell, with ropes attached to the heads of the piles to draw them asunder as the cuts were made.

Mr. Bramwell remarked that the question of cost had been put as though the work described were in itself a dock; whereas, if he rightly understood, it was merely the basin to contain the dock, and therefore the amount of money stated did not represent the cost of the dock and basin, but of the latter only. It had been stated that the depth of water upon the stone stringers was 18 ft., and that the basin was 311 ft. long and 211 ft. wide. There were, besides the dock, two short lines of railway in connection with it and the shore, each capable of receiving a ship. Taking the depth of water of 18 ft. above the stone stringers, and allowing for such a floating dock as this 8 ft. depth of bottom, it would leave only about 10 ft. for the draught of the vessel; and if that were so, this would be a very large work for docking small ships. He would be glad to hear what draught of vessel could be docked by these appliances, and whether the £125,000 represented the cost of the basin and railways, or whether it included the dock which was worked within the basin.

Mr. Bazalgette observed that the longer he lived the more impressed he was with the necessity of looking well to the foundations of works of this kind; he would feel disposed to exercise economy upon any portion of the structure rather than on the foundations. He thought that at Pola it would have been easy with a dredger first to have removed the mud upon which the béton had been deposited, and then to have founded it upon the solid rock. In that respect he regarded the work under consideration as an interesting experiment, and he would feel anxious to observe how far this work would, in the course of time, remain in position. He had himself been engaged recently in underpinning and deepening the foundations of two important wharves on the river Thames, which, for want of having been originally carried down to the solid ground, had given way, and the buildings were slipping into the river, after having been built and used 30 or 40 years. He was not able to follow exactly the remarks of Mr. Murray, who seemed to suggest the formation of a clay-dam in addition to the piling round the béton, which would be tantamount to forming an interior cofferdam of clay requiring a solid structure behind it. He did not see that any necessity for such an addition had arisen during the construction of the work. The piles seemed to have been kept in position by being strutted and bolted together and driven through the mud, and the principal merit of this structure seemed to be its cheapness and its simplicity. The béton was apparently allowed partially to set before being thrown into the water, and by that means probably the loss of lime and consequent deterioration of the béton were prevented, which would more or less occur if the béton was deposited, without some counteracting precaution, in an unset state. The plan which he had adopted with advantage was to pass the concrete through shoots so as to prevent the lime being washed out of the mass. Mr. Ridley in his Paper upon the Thames Embankment cofferdam * had given a description of a circular saw for cutting off the pile heads under water, which was supposed to be the first of its kind and had been patented; and, although that was somewhat different in principle to the one used at Pola, it was interesting to know that this advantageous mode of cutting off pile heads at a great depth under water had been employed in other cases and with the same success.

Dr. W. Pole remarked that the plan of dropping concrete into its place through a great depth of water appeared open to objection, as likely to damage the composition of the material and to affect its setting power. Some years ago he had occasion to go with the late Mr. Rendel, Past-President Inst. C. E., to see the harbor works at Marseilles, where concrete was used extensively in building walls under water. The plan there adopted was very ingenious. The concrete, being first properly prepared and mixed, was placed in a box about 3 or 4 ft. square, constructed in two halves, which opened on hinges at the upper part. This box was lowered through the water, and when in its place, by certain catches and chains, worked from the surface, the two halves of the box were separated, and the concrete spread itself quietly on the place it was intended to occupy, after which the empty box was drawn up and refilled. By this means the concrete was deposited

* *Vide* Minutes of Proceedings Inst. C. E., vol. xxxi., p. 3.

without danger of any of its components being washed away, and it was found to set perfectly in the usual time.

Mr. Harrison, Vice-President, said that if he understood the Author rightly, there was no clay conveniently at hand with which to make cofferdams; therefore, though Mr. Murray had suggested the practicability of constructing cofferdams in deep water, yet to make bricks without straw, as would have been the case here, was quite out of the question. He agreed, on the whole, with previous speakers, that it was most desirable in such situations to build a sea wall on a solid foundation; but he thought the Author had given reasons for adopting the plan that had been followed, which he was not able to controvert without much greater knowledge of all the facts of the case than he possessed. He had seen the same process as that described carried out in a depth of 40 ft. of water at Trieste, where the walls of the harbor were formed of béton within a framing of sheet piling, and in some cases with guide piles only, and planks placed inside, which were afterwards removed. There was not in this country the same material at hand to employ in such works; were it otherwise he was satisfied it would be more extensively used than at present.

Mr. G. B. Rennie said he had visited the works at Pola in 1858 during their progress, and had been conducted over them by Mr. Towle. He understood that this mode of construction was very ancient in the Adriatic, on account of the facility with which the Santorin and other materials employed were obtained; and these considerations in a great degree led to the method that had been adopted in making this dock basin. It had been estimated that the cost of a graving dock, like that at Southampton, of a length of 300 or 400 ft., was about £63,000. Now supposing the basin and railways at Pola to have been constructed at a cost of £120,000 as stated, and assuming that the dock itself cost another £100,000, for that outlay docking accommodation had been provided for five first-class vessels of from 300 ft. to 400 ft. long, and between 3,000 and 4,000 tons weight. That would reduce the cost per vessel to about £40,000 as against £60,000 in the ordinary graving dock. The whole docking arrangements at command, not merely the basin, must be taken into consi leration. He had been informed by an Austrian officer that vessels of 2,300 tons, such as the frigate Schwartzenberg, had been actually hauled ashore on several occasions, with great success, from this particular dock. It was evident from what had been done at Pola, that vessels of large size might be taken from the dock to the shore.

Mr. A. Giles remarked that Mr. Rennie's comparison of cost ought to have included the draught of water in the dock. In the Southampton dock there was a depth of 26 ft. of water over the sill at high tide, so that a vessel of that draught could be put upon the blocks. The Pola dock basin represented a depth of only 14 ft., and depth formed a material element in the cost, and ought to be considered in connection with it.

Mr. G. B. Rennie said the Kaiser, a line-of-battle ship weighing over 3,500 tons, had been lifted on this dock, and her load draught-line was 27 ft. The dock was in deep water when it lifted the vessel up, and was then transported into the basin.

Mr. A. Giles said in reply that in that case it ceased to be a dock and became a pontoon, the vessel being floated over a shallow sill; although it might answer all the requirements for docking ships.

Mr. Brunlees mentioned that a few years since, when at Fiume, he noticed some newly-constructed jetties made of concrete; but in that case the concrete was in blocks placed upon a stone bank, built up from 50 ft. to 57 ft. below low-water level to within 20 ft. of the surface. The top of the bank was levelled for a width of 47 ft., the land slope being 1 to 1 and the sea slope 2 or 3 to 1. This bank was formed of stones of all sizes, thrown in from barges and flats, and cost the Austrian Government 2s. per cubic yard; but the cost of the concrete blocks was 14s. 3d. per cubic yard. The concrete was formed from a compost of 6 parts of Santorin cement, 2 parts of slaked lime, and 1 part of sea-sand, which, after being well worked together, was mixed with clean small broken stone in the proportion of 1 to 1. The angles and sides were filled in with pure cement, and the blocks, when finished, were carried about 300 yards.

With regard to the foundations of the walls of the basin at Pola, he observed that if the mud under the wall was very soft, he would have no hesitation in putting the béton upon that mud, because it would sink through it and take its own position

on the bottom, and carry the superstructure just as well as if the mud had been removed. If the mud was comparatively hard, then he thought it would have been better to have removed it altogether previous to putting in the blocks.

Mr. J. Grant asked the Author whether he had made a comparative calculation of cost between the plan he had adopted and that of dredging out the foundation, as suggested by Mr. Bazalgette, and putting in the béton or concrete soon after being mixed, or in the form of blocks. Both methods had been adopted in Great Britain and in France. The plan of making the blocks, and of letting them harden for some time before putting them in place, and been extensively adopted. On the other hand, the plan of lowering the concrete through shoots, or by means of boxes or skips made to open, as mentioned by Dr. Pole, had also been followed. Each mode had its advantages. In the case of an embankment wall about to be commenced on the Thames, it had been determined not to remove a certain thickness of sand and fine gravel, which was too deep to be removed within the means at disposal, but on this stratum it had been resolved to form a foundation of two or three courses of concrete blocks, made of ballast and Portland cement in the proportion of 6 to 1. Above these the concrete would be put in after the usual manner as the tides permitted. Timber was a costly material, and he thought that if its cost could have been saved, it would have gone a long way towards making the wall wider at the base and narrower at the top, yet on the whole cheaper. As a general rule, concrete which had to be lowered through water must to a certain extent lose in strength. He had found that if concrete was allowed to commence setting for a certain number of hours after being mixed, and then passed through water, it would not be equal in strength to what it would be if allowed thoroughly to set out of water, or in blocks made and kept for a time above ground. Whatever strength was thus lost in the concrete was an equivalent to an increase of cost.

Mr. A. Giles observed that the Author had asserted that the Austrian Government had abandoned the idea of an excavated dock in consequence of the treacherous nature of the ground, and that the difficulty of constructing a cofferdam and getting the water out to enable them to proceed with the excavation had deterred them from taking that course. But it was stated that four pumps 32 in. in diameter, and with a stroke of 30 in., were sufficient to keep the basin dry with a head of water against it of 20 ft. However, he was of opinion that an efficient cofferdam could have been put up more satisfactorily and at less expense than the system of construction that had been adopted. The basin was 211 ft. wide and 311 ft. long, which gave an extent of wall of 1,046 ft.; now allowing 1,100 ft. for the length of the cofferdam, he thought he could have put it down for £20 per foot. It might have been supposed in the first instance that the cofferdam was not put in because there was no clay readily at hand for the purpose, but it appeared clay was used to some extent, and it might therefore have been found for the cofferdam. If he could have put in a cofferdam for £22,000, he could have built the walls for £20,000 more, or £42,000 for the whole dock; the caisson cost little over £3,000, and these items together amounted to £45,000. There was no mention of cost in the Paper, but that must be taken into account in considering whether a work was well done and worthy of imitation; and it was said that the cost was £125,000. The Author had given 2,200 cubic yards as the quantity of prepared béton, which it was said it took 82 men 18 days to prepare; according to which a man could only prepare 1½ yard of béton per day. That must have been expensive for labor if not for material. If the Author would give the cost of labor, as well as the cost of the work, it would enable an opinion to be formed whether in this country a Balance Dock might be built on a bottom of mud, or whether it would be better to go down to the solid rock.

Mr. Redman said he thought it was unfair to contrast this work with others having a similar duty to perform elsewhere. Graving docks were admirably adapted to the United Kingdom, where there was a large rise and fall of tide; but, in a comparatively tideless sea, they were to a certain extent inapplicable. He considered that the outer basin of this system of dock and slips was laid out for the protection of ships from the sea during the process of docking, under the great changes of weather that occurred in the Adriatic, and possibly also before being transferred to the slipways. In making any comparison of the kind referred to, the cost of the cubical

internal capacity of the outer basin should be compared with the cost of a graving dock. This came to considerably over £1 per cubic yard of internal sectional capacity for the Pola dock—a high price. However, this system enabled two or more vessels to be docked *in transitu*, and there were slips or railways in connection with the basin, so that there was available dockage for five vessels; and taking the total cost at £125,000—which were the figures quoted—the cost was only at the rate of £25,000 per vessel.

It had been stated that a large iron-clad vessel had been docked in this basin, in which the available depth of water was from 13 to 15 ft., whereas the vessel referred to drew over 27 ft. of water. This proved that the balance dock could be taken outside the basin, submerged, the vessel put on, and the receptacle pumped out and taken into dock; so that evidently the comparison with ordinary graving docks did not hold.

With regard to the question of forming the foundation of the walls either on the surface of the clay or mud or on the rock, no doubt the walls might have been carried down to the rock by dredging a trench, without—as Mr. Giles proposed—putting in a cofferdam at all, or by caissons or cylinders; but looking at the limited depth of the basin, and the appliances for transferring a vessel to a higher level by means of slipways, such an outlay would undoubtedly have increased the expense of that particular portion of the work, which appeared to be about half the total cost, by about 50 per cent.

Mr. J. M. Heppel said that Mr. Rennie's explanations suggested the inquiry, Where was the necessity of any close basin at all? Because, if the pontoon, or float, or lifting dock, could be submerged, so that it could rise and fall and be floated into the basin, and allowed to settle upon the stringers, and the railway brought to such a level that the ships could be hauled away upon it, then a simple submerged platform at this level without any enclosure would have answered all the purposes required. Mr. Redman suggested that probably it was to protect the vessels from the effect of the waves; but if that were so, there would be no necessity to make the walls so completely water-tight, for if they were intended simply to answer as a breakwater to keep the vessel from being knocked about, a construction not water-tight would have answered the purpose just as well.

Mr. J. Grant asked the Author—

1st. The cost per lineal foot of the basin walls complete, including timber and rubble?

2d. The price per cubic yard of the Santorin béton?

3d. The price per cubic foot of the timber used in the dam?

4th. The general rate of wages paid to the various classes of workmen employed?

Mr. Bramwell remarked that Mr. Redman had spoken of £125,000 as being the total expenditure on the apparatus which would dock the vessels, but he thought that sum did not include the cost of the floating dock, for which probably another £125,000 would have to be added. He would be glad if the Author would state the total cost.

Mr. J. N. Douglass remarked that, in this case, with a depth of water of about 15 ft., and under that a bed of clay varying from 2 ft. to 12 ft., and underlying that rock with a surface dipping from 2 deg. to 10 deg., there were all the elements of unequal settlement and slip, which the Author had ingeniously provided for; the first by the open joint at the end of each section, and the second by the timber key in each of these joints. He thought that by the system adopted there would have been no difficulty in making a continuous béton wall founded upon the rock, and that this could have been done with but little additional cost, and without removing all the mud. One-third might have been dredged down to the rock in sections the whole width of the wall, at equal distances, and those pits when filled with béton would have formed such supports for the wall as to render it perfectly safe from immediate or future settlement. He feared, notwithstanding the open joints had been filled in, that future cracks would occur; and he would ask Mr. Towle whether, in the event of such cracks manifesting themselves again at these weak parts of the wall, he had considered the question of a remedy.

Mr. H. E. Towle, in reply upon the discussion, said that some misapprehension appeared to exist with regard to the functions of this dock. Looking at it as a balanced dock *per se*, if it was used without a basin it would be just as effective, and more so, than the one mentioned by Mr. Giles, built with a cofferdam, which could

not be moved; whereas this floating dock could be taken anywhere. As to the dock itself, the floating power of each foot in depth of water was sufficient to lift a weight of 1,000 tons, and a vessel over 5,000 tons had been lifted. It was a question of locality whether an excavated dock or a basin could be built cheaply or not. In this case he had to go many miles for what clay he could get to the limited extent that he was enabled to use it.

It had been asked, Why pump the basin dry? That was for the purpose of getting access to the bottom of the dock in case of repair being required.

The experience obtained had suggested some things which might be advantageously changed or modified if the same result was to be accomplished again under similar circumstances; but the case was an unusual one, and was entirely without precedent, and demanded prompt decision and action.

It was true the Austrian engineers repeatedly came to look at the work, and to see the plans and drawings; but, without exception, till the basin was actually pumped clear of water, they contributed nothing but grave doubts of success, and positive declarations that the basin would be a failure. The basin was not to sink the floating dock in at all, as that operation was performed outside, where the water was about 40 ft. deep; but it was to form a level surface on which to rest the floating dock when a vessel was to be hauled out from, or returned to, the floating structure, or whenever it was desired to inspect or repair the bottom of the dock itself. And, inasmuch as the dock when tested did raise the Austrian ship of the line the Kaiser, which, with its stores, actually weighed 4,223 tons, and at the same time lifted guns and other ballast to make the entire load—ship and all—up to 5,066 tons, he could not assent to the remark, that it was a very large work for docking small ships. Besides, the work would accommodate four more large vessels at the same time upon the railways. In fact, the Pola floating dock would take in and raise a vessel weighing 6,500 tons, and having a draught of 25 to 27 ft.

The problem to be solved was as follows:—A basin had to be constructed measuring somewhat over 200 ft. by 300 ft. on the sides inside. This basin had to be finished with a perfectly level bottom, and capable of sustaining a solid load, uniformly distributed over half of its surface, of several thousand tons. The basin enclosure had to be capable of being pumped dry, both during the period of construction of the bottom and also after the work was finished. The enclosing walls or dam were required to resist a difference of inside and outside water pressure of 20 ft. during the construction of the work, with an outside head of 25 ft. to 40 ft. water; and after it was constructed it had to resist whenever required a maximum difference of pressure, inside and outside, of about 15 ft. of water, the greater head being invariably upon the outside. The site of this basin was in a harbor whose bottom and shores were totally unreliable, and full of irregular cavities and passages of a honeycomb nature. These cavities had, on two different previous attempts to excavate for ordinary stone dock constructions, caused total failures and abandonment of the attempts, with great loss of expended money, which was due to the fact that, at a depth of about 16 ft., the rock bottoms of the excavations were crushed through by the blasting operations, and communications through the cavities directly to the sea resulted. The bottom of the harbor of Pola appeared to be of this unreliable character; but that bottom was covered with a particularly tough material, good for anchorage, from 2 ft. to 12 ft. in thickness. For the first 2 ft. it was soft and incompact; deeper down it became more solid; and where it was 12 ft. deep it was so solid throughout that a steel rod or probe 1½ in. in diameter was with difficulty forced through it by a load of about 500 lbs. weight. A stratum of 4 ft. to 6 ft. of this mud held piles well enough when they were properly connected together above, and less was not safe. This tenacious mud would, exclusive of the upper surface, sustain without yielding, a load of several tons per square foot. It lay all over the site of the basin, in one unbroken tough sheet, covering the rock on which it rested, and covering at the same time all cracks and subterranean and submarine passages and water-ways, which were known to pervade the earth's crust in the vicinity of Pola.

Under these circumstances, and with a site exposed to sudden and violent gales of wind, the question arose, how to build a water-tight basin? Was it safe to remove the water-tight homogeneous and compact natural plaster, or stratum of mud, which

in the absence of tidal currents had settled upon the doubtful parts of the bottom? And if so, should it be removed in a trench wider than the base of the wall before forming, and then in some way anchoring the wooden moulds for the béton sections? Or should it be removed within the wall space bounded by the lines of sheet piling after it had been driven in? If removed before the wood-work was put in position, there would have been a depth of 25 ft. to 50 ft. of water, and wooden caissons (sheet piling being out of the question) of at least this height must have been constructed of considerable length, and without internal struts and ties, and at the same time of sufficient strength to be launched from the shore and handled about till adjusted and securely anchored in place. These would have required great accuracy in their construction, that their lower edges might conform to the irregular surface of the rock bottom. Some of them, with the thickness of walls which were adopted, would have been simply huge boxes without top or bottom, and deficient in bracing, and would have had a length of 75 or 80 ft., a height of 40 to 50 ft., and a horizontal thickness of 20 ft., and one such would have taken for its construction about 15,000 cubic ft. of timber, which of the kind available at Pola would have required 225 tons of ballast to sink it.

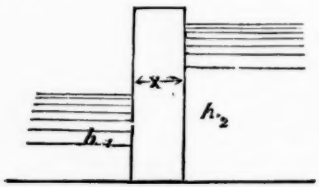
Again, admitting this system of large portable moulds or caissons to be quite possible of themselves, though a caisson of 25 ft. in depth had been the largest hitherto achieved, he had seen in Pola harbor the frames and caissons of similar moulds of only 12 to 15 ft. in depth wrecked in much less exposed situations, and destroyed in a moderate gale of only a few hours' duration. The enormous cost of this plan would be apparent, without figures in detail, when it was considered that it involved expensive dredging, costly caissons, a greatly increased quantity of béton, to replace the excavated mud, and the difficulties of constructing and maintaining the work intact during its progress. He admitted however without reserve the correctness of the general principle of starting foundation walls from the solid rock, provided it could be carried out practically without counterbalancing attendant evils. Had a trench been excavated for the wall of the basin there would have been risk of uncovering, on either side of the line of the wall, passage-ways through the honeycombed rock, such as caused the failure and abandonment of the works previously attempted for an ordinary excavated dock; and he thought it imprudent to incur this risk when a cheaper and safer method was available for constructing the wall. Mr. Murray seemed to have considered the problem in hand as one more particularly raising the question of the superiority of temporary cofferdams; but the problem was to get a permanent water-tight masonry basin, which could be laid dry at any time under a possible maximum head of about 15 ft. of water.

Béton was the cheapest material as well as the best for the permanent structure; and even if its cost was two or three times greater than that of a clay cofferdam, the latter was not required at all by his method of construction. The object was to build the basin walls as economically as possible with or without cofferdams. To have driven a cofferdam would have been perfectly practicable; but while it was serving its purpose as a dam, the timbers in it could not have been used for the timber-work in the bottom of the basin, as was the case with the sheet piling which was cut off after the walls had hardened. And then, again, the quantity of timber required for a temporary clay cofferdam, and that required for the bottom and other parts added to it, would, to say nothing of the difficulty of getting proper clay, have made an exterior clay cofferdam excessively costly, even with the thinnest possible permanent wall that would have served the purpose. The cofferdam must have been very thick and ponderous if the water was taken out to the bottom rock, which in the northern part was about 50 ft. below the water level outside; he knew of no such dam in such an exposed situation, and it would have been very expensive. The rotative forces on such a dam, the earth being removed from the inside, to be in equilibrium with the mass acted upon by gravity alone, would have required a thickness of between 19 and 20 ft. of wall; and the forces tending to slide the dam horizontally along the rock on which it rested, with a coefficient of friction of 0.25, would require to keep them in equilibrium a thickness of wall of more than 48 ft., and in the deeper water still more. If the inside wall, with such an outside cofferdam, only went down and was made water-tight with the shallow bottom of the basin, then when the exterior dam

was removed and the basin pumped dry inside, as it had been repeatedly, the basin itself, if it held together, would have floated.

CALCULATIONS RELATING TO THE STABILITY OF THE BASIN WALLS AT POLA.

Problem 1. Required the thickness of a rectangular wall or dam, 35 feet high, of Santorin béton, to sustain a pressure from sea-water, upon one side having a head of 34 feet, and upon the other side a head of $(34-17\frac{1}{2}) = 16\frac{1}{2}$ feet.



Sea-water weighed 64 lbs. per cubic foot.
Santorin " 120 lbs. "

Let h = height of the wall or dam, and l = length.
h_1 = height of the water outside.
h_2 = height of the water inside,
w = weight of the fluid per cubic foot.
w_1 = weight of the material in the dam per cubic foot.
x = thickness of the dam.

The dimensions are in feet and weights in lbs.

For the (outside) hydrostatic pressure P_1.

The area pressed ..... $= h_1 l$;
Centre of gravity below surface..... $= \frac{1}{2} h_1$;
Density of fluid..... $= w$;

$$\therefore P_1 = \tfrac{1}{2} l h_1^2 w, \quad . \quad . \quad (1.)$$

Centre of pressure on outside, above (a) axis $= \frac{1}{3} h_1$;

$$\text{Statical moment of } P_1 = \tfrac{1}{6} l h_1^3 w. \quad (2.)$$

Similarly, for the (inside) hydrostatic pressure P_2.

$$\therefore P_2 = \tfrac{1}{2} l h_2^2 w; \quad . \quad . \quad (3.)$$

and in reference to axis (a) the

$$\text{Stratical moment of } P_2 = \tfrac{1}{6} l h_2^3 w. \quad (4.)$$

Let R = the resuitant of the pressures $= P_1 - P_2$; this gave for R

$$P_1 - P_2 = \tfrac{1}{2} l h_1^2 w - \tfrac{1}{2} l h_2^2 w, \text{ and}$$

$$\therefore R = \tfrac{1}{2} l w (h_1^2 - h_2^2). \quad . \quad . \quad (5.)$$

Let z = the distance this resultant acted above the axis of rotation (a), then its statistical moment was

$$R z = \tfrac{1}{2} l w z (h_2^2). \quad . \quad . \quad (6.)$$

From equations (2) and (4) were obtained the following expressions for the value of this statical moment:

$$R z = \tfrac{1}{6} l h_1^3 w - \tfrac{1}{6} l h_2^3 w; \text{ reducing}$$
$$R z = \tfrac{1}{6} l w (h_1^3 - h_2^3) \quad . \quad . \quad . \quad (7.)$$

and substituting the value of R in equation (5) and dividing, there was obtained

$$z = \frac{4}{3} \frac{(h_1^3 - h_2^3)}{(h_1^2 - h_2^2)} \quad . \quad . \quad (8.)$$

The sum of the statical moments of the water pressures taken with respect to (a) the axis was as above ascertained, (Equation 7),

Formula $\quad R z = \tfrac{1}{6} l w (h_1^3 - h_2^3)$,

tending to turn the wall inward. To resist this, there was the weight of the wall or dam itself, and the pressure of the filling of earth upon the inside of the basin, which latter for the present would be neglected.

OF THE RESISTANCE OF THE WALL OR DAM.

The volume of the wall..... vol. $= x h l$;
The weight of the wall..... $W = x h l w_1$;

Its statical moment about (a) was

$$W \times \tfrac{1}{2} x = \tfrac{1}{2} x^2 h l w_1; \quad . \quad . \quad (9.)$$

and for equilibrium

$$\tfrac{1}{2} W x = R z. \quad . \quad . \quad (10.)$$

Now substituting in (10) the values from equations (7) and (9) and afterwards reducing and solving,

$$\tfrac{1}{2} x^2 h w = \tfrac{1}{6} w (h_1^3 - h_2^3),$$
$$x^2 h w_1 = \tfrac{1}{3} (h_1^3 - h_2^3) w,$$

the general formula for thickness was obtained.

$$x = \sqrt{\frac{1}{3} w \frac{h_1^3 - h_2^3}{h w_1}} \quad (11.)$$

Substituting the numerical values of Problem 1,

$$x = 13\tfrac{3}{10}.$$

Problem 2. To find the thickness (x') a cofferdam must have to stand upon the rock bottom, without either water or earth inside, taking the material at 120 lbs. per cubic foot for the clay dam:

The cofferdam had a height h $=35+12=47$.
The head of water was..... $h_1=34+12=46$.
$h_2 = 0 \quad w = 64 \quad w_1 = 120$.

Substituting in the general formula (11) for thickness,

$$x = \sqrt{\frac{1}{3} w \frac{h_1^3 - h_2^3}{h w_1}} = \sqrt{\frac{1}{3} \times 64 \frac{46^3}{47 \times 120}}$$
$$x' = 19.1833;$$

therefore for equilibrium against rotation the thickness was nearly 20 feet.

For equilibrium against sliding from the water pressure, which was over 30 tons per lineal foot of the dam, with a coefficient of friction of 0.25, the thickness would have to be more than 48 feet. Of course when the water was deeper, as at the north-west corner of the basin, the thickness in either case must be correspondingly greater.

The plan for removing the mud, instead of building upon it, by dredging to the rock bottom inside the timbers forming the sheet-piling walls, received much attention. No doubt it was the most certain way to found the walls upon a solid bottom, but it presented the disadvantage of greater cost. The wood-work, sheet-piling, etc., would have required bracing and strengthening, and also loading down by ballast, if the interior mud supports to the piles had been removed. The dredging itself in the narrow space of from 15 to 20 ft., encumbered by the upper cross frame-work and bracing and the staging piles, would have been troublesome and expensive. The walls if carried down on an average of 6 or 8 ft. deeper than the water, would have required 20 per cent. more materials in the Santorin béton parts, and their cost would have been increased in this proportion.

It would, he thought, be admitted that so long as mud, or any other material, under a wall could not escape, even if fluid, the wall could not go down by settling vertically. And if such mud in a tight enclosure was so powerfully pressed that its fluid parts disappeared, as the water in a submerged sponge would do in a press acting under water, and left the solid material, which never again would have to sustain as much pressure as it had already received, then such a wall, so far as its mere weight was concerned, had an adequate support. Suppose a great amount of lateral friction were now brought about, by embedding this wall upon either side in such wood and earth work as the Santorin walls at Pola had provided for them, additional vertical as well as lateral support would be given to the wall; in the same way that an ordinary pile got a great share of its sustaining power from side friction. This friction was increased at Pola by the use of fine sand, which was carefully thrown against the outer sides of the walls, and which, by constantly insinuating its particles under the gentle action of the water and of gravity, continued to give increasing stability to the wall.

Reference had been made to jetties in France constructed of béton blocks, but these jetties would allow the water to flow from one side to the other even at a moderate depth. He had made comparative valuations of cost between the method adopted and that including dredging out, and the economy was in favor of the adopted plan.

Respecting the cakes of concrete referred to by Mr. Grant, if he meant small masses of a few cubic metres such as were used at Marseilles, Caen, and some other places, for breakwater works, no estimate was made, for the reason that no plan occurred to him in which such cakes could be of effective service, or at all compete with the large cakes containing 1,500 to over 2,000 cubic metres. That there would have been less material in a wall with a wide base and narrow top was true, but in the present case it was desired to hold the blocks under perfect control during the progress of settling. If the sides of the enclosing wood-work had been such as to allow the inverted wedge form to be given to the cross section of the blocks, any settlement of them would have caused the wall to drop away from the sides, and be free to yield to any forces acting to throw it out of the desired line of the wall, and also impair the foundation. Besides, a width of from 15 to 20 ft. was not too much on the top surface of the walls, and a greater width below would have prevented rather than facilitated the immediate subsidence of the wall to its lowest point, which was promoted by top-loading the walls, and removing the water from one side to a greater extent than would occur again.

The cost of Santorin béton from 1857 to 1860, at Pola, including all materials and labor when deposited in a trench, was about 80 Austrian florins per cubic klafter, or approximately 10 florins per cubic yard. The cost per cubic foot of pine timber in the dam, of 1 ft. by 1 ft., was, at 3 florins 33 kreutzers per lineal klafter, about $\frac{2}{3}$ths of a florin. Round pine piles cost about $\frac{1}{3}$d florin per lineal foot; and very large square oak timber cost 2 florins per cubic foot.

The wages of a mason were ..1¼ to 2 florins per day.
" " mortar-maker were.....1¼ " "
The wages of a laborer were..1 to 1¼ " "
" " carpenter were1¼ to 2½ " "
Hire of cart and two horses..5 " "

In May, 1859, a cofferdam was made in the ordinary way at Pola, after the basin had been pumped out, on the other side of the same island, where the greatest depth of water was 15 ft.; but it failed.

Santorin béton had invariably been spoken of as if it were the same as ordinary concrete or béton made with Portland or Roman cement, or of some of the various kinds of hydraulic cement; but this was an erroneous idea. When newly made it was not fit for use until it had been exposed to the open air for a period of from 2 to 6 days, in heaps of about ½d of a cubic yard each. This was the size of the batches, compounded of 7 cubic ft. of Santorin earth, and 2 cubic ft. of lime paste, which formed Santorin mortar of remarkable strength, to which was added 7 cubic ft. of broken stone. These together made 9 cubic feet of Santorin béton. When this béton was to be used in water 10 or 15 ft. deep, the heaps were broken with a spade or pick into pieces convenient for shovelling into barrows, coarse and fine together, and simply "dumped" into the moulds in horizontal layers uniformly distributed, which was ascertained by the foreman in charge continually measuring with a rod suitably marked. In depths not exceeding about 20 ft., the cementing materials were not washed away from the fragments of béton and pieces of broken stone, but reached their positions in the wall in proper condition to unite firmly with the rest; but in the case of the deep blocks between 25 and 40 ft. in vertical thickness, he found it advisable to guard against this wasting action of the water during the fall of the béton to the bottom. Baskets, spouts, tubes of canvas, boxes, such as had been used at various works for depositing concrete, which opened in two parts, and cloth bags in which to lower the béton by ropes, and then untie and deposit the contents, were duly considered. But the unusual depth of water and the great quantity of material to be let down—some of the single blocks contained 2,200 cubic yards of béton—and the expedition required to complete one block in a reasonable time induced him to seek a more expeditious way of procedure, and in the end he simply deposited the heaps of 9 cubic feet each in a solid unbroken mass, in the deep water; there the lumps were crushed by iron rammers fastened to the ends of long rods for handles; this expedient overcame all difficulties, and was at the same time the most economical.

The Santorin earth, damp and loose as usually measured from the heap, weighed 50 lbs. per cubic foot. A cubic foot of Santorin earth absorbed 30 lbs. of water, and the simple addition of the water caused the earth to shrink two-thirds its original volume. It was very similar to puzzuolana and was of a volcanic nature; a large percentage was in pieces of about the size of a pea, diminishing down to sand. Mixed with common lime it made a very hard and strong material; and he had seen entire arches made of it, and it was capable of being worked like stone.

THE VALUE OF ARTIFICIAL FUELS AS COMPARED WITH COAL.*

By JOHN WORMALD, C. E.

The question at issue really is, why should artificial fuels be worth considering only during the existence of a coal famine? We are well aware that artificial fuels are in daily use, but I ask to what extent, as compared with the resources we have for producing it. There are thousands of tons annually of really good fuel cast on one side, destroying otherwise profitable land, that, if only dealt with by known processes, would be almost as valuable as the coal itself in its units of work. Rises in the price of coal above the ordinary level are quickly followed by the appearance of this waste in the market, and not till then is it disposed of commercially, after laying for years exposed to the weather during the low or ordinary price of coal; it must be remembered, too, that this residue under consideration, through such exposure, gradually loses in value for heating purposes, and is reduced in bulk through dirt and dust being carried away by wind, partially destroying useful land in the neighborhood, while the slow process of oxidation reduces the percentage of heating power. Thus, if after years of deterioration at the pit's mouth, this stuff is found to be of marketable value, it surely ought not to be allowed to accumulate to the extent it does.

* The Scientific and Mechanical Society, Manchester.

The question is—that, if for the future immediate advantage is taken of this refuse when brought to the pit's mouth, to what extent will it relieve us? Professor Gardner, at the Polytechnic Institution, London, has been telling us lately that there are about 24,000,000 tons of this smudge or waste brought up to the surface annually, but as he has taken a percentage of a rather high total annual get of coal, viz., 140,000,000 tons — whereas it is, I believe, about 120,000,000 tons—we may safely assume that there is not less than 20,000,000 tons of waste brought up with the present annual production of coal.

There is no reason why at any time this improperly so termed waste should not be made good use of, let the price of coal come down to what it may; and we must hope that the inertia lately given to the fuel question will start enterprise in the right direction as far as this item is concerned. It may be argued that coal dust is used in the manufacture of patent fuels; but whatever is used in quantity there is an undoubted accumulation of this so-called waste, and this waste, if not allowed to deteriorate by long exposure to the atmosphere, may be made as commercially valuable as the selected class of dust.

For domestic purposes I don't think that patent fuels, in the ordinary sense of the term, are well adapted; but if the 20,000,000 tons just referred to was rightly made use of, it would reduce the existing draw upon coal for steam purposes considerably. I have drawn attention specially to this coal residue question to show that it forms considerable bulk when compared with the staple fuel itself, and, as its cost of get or production equals that of the coal, it is of no minor importance that use should be made of it with the best results attainable, especially when we find the demand for fuel in all directions increasing in the ratio that it is doing.

The question now arises: What is the best way of treating this residue or waste? As it really forms the foundation in bulk of patent fuels as a rule up to the present time, it may and will be assumed that there have been various ways of dealing with it so as to make it a fuel of commercial value. Therefore, for the purpose of illustrating superficially what has been done to attain this object, I have referred back to what has been patented directly for this purpose.

We are supposed to find in the patent records all that is of value, and, of course, plenty that is not of value; and I have taken this course of obtaining what little information I can lay before you this evening for the purpose of connecting the fuel history of the past with the present. To more clearly explain the connection, I have considered it worth while to diagram the mixtures in the relative proportions as set forth in the respective specifications, but only in such cases which I have considered interesting for comparison. In following them up we certainly shall find a few extraordinary-looking proportions both in the nature and in the quantities of the several ingredients, but as to the merits of such mixtures or compounds for the purpose required, I will leave the meeting to judge for itself. In searching back through the patent records, the first published specification I can find in connection with fuel is dated April, 1773—exactly one hundred years since. I believe patents for the same subject had been granted long prior to the above date, for I remember some time back noticing in "The Engineer," in one of a series of articles on peat, that a patent was granted to one William Fallowfield, in 1727, "for the use of charred peat in the smelting and manufacture of iron." In the patent of 1773, just referred to, the specification relates chiefly to the purification of coal for smelting purposes, and we may reasonably infer that at this time serious attention began to be paid with respect to fuel, for down to 1792—a period of nineteen years—we find the same John Barber figuring in the patent list, and with the same object.

In the year 1799, which we may call in round numbers nearly three-quarters of a century back, we find the first patent record of a composition or artificial fuel, in which the patentee describes the machinery for separating or screening the coals, taking the small or dust of the same as a base for his fuel, which is to be mixed with any portion or all the ingredients named in the diagrams (1799), in which the various ingredients are simply named, there being no proportion specified. He proceeds to say that they must be mixed together and ground in water in a wooden vessel, after which he moulds the composition into cakes or balls for use. I wish to draw particular attention to this three-quarter of a century old patent, for I think we see there the secret of nearly, if not all, of our patent fuels up to the present day; and it is strange

to watch how persistently fresh patents are obtained, almost weekly, for artificial fuels, the component ingredients of which come, in one way or another, within the list before us. The patentee evidently went in for everything and anything that at all stood a chance, and it appears he got exhausted at last when he had to connect "broken glass" with "any other combustible ingredient." In 1800, the year following, we again find a list of ingredients much resembling the former, but it may be noticed that peat is here mentioned, a substance that must have been quite unknown to the former patentee, otherwise he surely would not have omitted such an important ingredient in preference to broken glass. The patentee in this case, too, does not give any definite proportions to his mixture, but specifies that "the proportions of the ingredients vary so as to suit different purposes." The list is given under 1800 to show the resemblance between the two. Twenty-one years later, say fifty years ago, we get a mixture that has, I believe, been used for an artificial or patent fuel to a far greater extent than any other—small coal and tar, in proportion of 3 quarts of the latter to 1 bushel of the former. This is the first patent during the twenty-one years on the immediate subject in question, but I think we may safely assume that during this period artificial fuel must have kept in use more or less, and it seems strange that after such a lapse the patentee of the previous mixture should burst out with such a simple modification of his first specification. Perhaps he had run the full term with the patent of 1800, and no doubt in the meantime he had ample experience from actual practice as to value, both in cost and work, of various mixtures and proportions of the ingredients named in his first specification, and at last comes down to the simple coal and tar mixture made into bricks, and for which he secures a fresh patent. The next mention in connection with combined fuel is in 1824, when we get a mixture of one-third to one-fifth of bituminous coal, and the remainder stone coal, or culm, and I think this was simply mixing the one with the other and using it in the ordinary way. In the year following, 1825, we have gas-tar and clay, with sawdust or tanner's bark, or the refuse of dyers, wood, or any species of wood sufficiently granulated or reduced, or turf, or straw, or bran. The patentee gives a proportion of one fourth gas-tar, one-fourth clay, and two-fourths of any other ingredients, but a proportion that he says burns very bright is one-third tar, one-third clay, and one-third sawdust. The patentee also adds that gas-tar boiled loses much of its smell without materially injuring its quality. He formed his composition into squares or lumps, and exposed them to the weather for a few months.

1826 brings us to a proportion of one-fourth dung, one-fourth sawdust, one-fourth tanner's bark, and one-fourth mud, the above being mixed with sufficient water to bind them well together. Afterwards it is formed into squares, then dried by artificial heat and dipped in hot tar. I really don't think this made a bad fuel, but when we come to such ingredients as tanner's bark, sawdust, and dung, in the large proportions as specified here, we should fail in quantity, whatever kind of a fuel it might make. If we could only introduce a little more of the mud business in our preparation of artificial fuels I'm sure it would be hailed with delight, especially by our corporations.

We now pass over a period of seven years, during which time artificial fuel productions—as far as patents go—lie dormant, but in 1833 we have a specification claiming a mixture of sea coal with brick earth, blue clay, river sand, or deposits of running or stagnant waters. The proportion of coal to be equal to that of either of the other materials, and to be mixed like mortar with tar and made into cakes or balls. The ingredients here contained may be taken from the 1799 list, substituting the river sand for broken glass.

Three years later, or in 1836, we get an extraordinary combination of ingredients, and, from the finite proportions of certain of them, I should imagine that the specification is the result of a long and tedious series of laboratory experiments and tests. The patentee begins with peat, of which he takes one ton in its raw or charred state, and to this he adds 30 lbs. of crude nitre, 14 lbs. of alum (for preventing smoke), 14 lbs. of linseed, 14 lbs. of resin, asphalt, or naphtha, 150 lbs. of coke, 168 lbs. of green vegetable matter and 156 lbs. of animal excrements or other animal matter. For use the mixture is formed into bricks. I cannot say how the peat was dealt with so as to amalgamate properly with these particular substances, but there must have been some means of masticating or triturating it, otherwise perfect mixing would be

impossible, as also the formation into bricks.

A year later—1837— we reach the first mention of treating peat alone, as far as concerns operations for the purpose of converting peat, moss, turf, or bog into fuel. It is first cut up or triturated, and then compressed and dried by artificial or other means; hydraulic presses, levers, and screws are mentioned amongst the appliances for compressing.

In the same year we get a well-known name in connection with fuel. C. Wye Williams mixes peat, after mastication, with sand finely powdered, limestone powdered or ground, coal slack, or quick or hot lime. I should in this case expect that the expense of first preparing the peat for mixture, and added to that the cost of grinding or powdering the limestone or sand, would not tell favorably as regards a marketable price in comparison with coal, especially of late years.

About this time the artificial fuel question seems to have received a considerable amount of attention, and in 1838 I find five patents secured for the same. The first of that year illustrates how we still keep to the old ingredients, with perhaps a slight variation in proportions. The patentee in one case adds to one ton of small coal 30 lbs. of tar, 180 lbs. of dry mud, clay, or marl, then mixes with 50 gallons of water, and adds 30 lbs. of lime or chalk. Again, to 10 cwt. of coal dust he adds 5 cwt. of peat, 5 cwt. of sawdust, 200 lbs. of clay or mud, 30 lbs. of lime, and 30 lbs. of tar, the whole being mixed in water and then formed into bricks. Another of the mixtures of the same year is: 7 parts of fullers' earth or strong blue clay, 2 parts of tar, 8 parts of small coal, and 3 parts of mud, the mixture being then formed into bricks for use. I certainly should think this a doubtful fuel, considering there is 50 per cent. of clay and mud to 50 per cent. of small coal with tar in it. Again, in the same year we get 10 per cent. of tar, 18½ per cent. of cinders, peat, or sawdust, 18½ per cent. of clay, sand, or chalk, 50 per cent. of small coal, and 2½ per cent. of acids for another combination. We also in this year again find C. Wye Williams patenting a means of preparing peat, moss, or bog, by pressing it or mixing with it bituminous matter, and we may close the year 1838 with a mixture consisting of 13 cwt. of coke, 4 cwt. of clay or mud, and 1 cwt. of liquid pitch.

In 1839, there is again repeated the "obtaining a fuel by mixing tar or bituminous coal with inferior coal dust;" this is followed up in the same year by Lord Willoughby d'Eresby, patenting the compression of peat in the raw state, and without cutting it up.

In 1840 we find a specification of a mixture to be employed for buildings, mouldings, castings, statuary, imitation of soft or hard rocks, etc., and also to be used as a fuel. Whether any buildings were ever constructed of this fuel or not I am not in a position to say, but I should imagine that the insurance companies would fight shy of them. While upon the subject, I may as well mention as a proof that even now there are people who, with the patentee of thirty years past, believe that for some reason or other it is advisable to construct our dwellings of fuel, for in a specification relating to building materials, dated as recent as last September, I find the following as an abstract: "The said invention relates to a novel treatment of bricks, unburnt clay, soft stone, chalk, plaster of Paris, and other like porous materials, whereby a new material is obtained, which possesses many advantages for building and other purposes. To accomplish this object the inventor takes common bricks, blocks of sandstone, or the other material to be used, and saturates the same with boiled coal tar, melted pitch, or other similar substance."

In the same year, 1840, we find 400 lbs. of tar and 105 lbs. of clay to one ton of small coal, made into bricks, followed up, four months later, by 20 lbs. weight of pitch to 1 cwt. of coal dust, moulded into bricks.

The year 1841 gives us three patents connected with artificial fuels, none of them varying from previous mixtures, with the exception that one of them contains ground slate.

In 1842 we find five specifications, the only one worth mentioning, specifying chalk lime, soft stone, bricks, all broken into small pieces and saturated with tar, and then used in the same manner as we use ordinary coal.

In 1843 we again get five patents relating to artificial fuels, one specifying certain proportions of pitch, coal, and coke ground together, and for every ton so ground is added 6 lbs. powdered resin, and 3 gallons of boiled linseed oil; another gives 10 per cent. of pitch or coal tar to 90 per cent. of

small coal, and to prevent smoke, there is added 2 to 5 per cent. of common salt dry, or alum dissolved.

In 1844 there are three patents connected with the subject, one of them being "for machinery for getting the moisture out of peat." At this time there seems to have been a fresh impulse given to the fuel question, very probably in the anticipation of locomotive requirements, for in the year 1845 there are seven applications named in artificial fuels, chiefly of the ordinary character, with the exception of one. The specification gives as this mixture: Gutta-percha $3\frac{1}{2}$ parts, coal dust 4 parts, sawdust 2 parts, and coal tar $\frac{1}{2}$ part. Whatever may have been the patentee's idea of the cost of such a fuel at the time, it is pretty conclusive what our own opinion would be now, when we look at the proportion to the whole of such an extraordinary ingredient as gutta-percha and its value. In the same year we find the usual mixture of coal dust with tar, and sometimes added a small portion of chloride of lime, or chloride of soda, or chloride of potash, to take away smell during combustion. We have at the same time "cementing coal dust with Ransome's silicious paste;" perhaps the latter might be used as suggested before, namely, for building materials.

In 1846, although we get six methods of treating fuel, they are of a very ordinary character and the only change is one mentioning the saturation of peat with tar, oil, etc.

In the year following there is a complete dearth as far as fuel patents are concerned, for there is not one registered for that year; but in 1848 we again get a start with four; but I find that there is still but very little deviation from former mixtures.

For the three years including 1849-50-51, I find nineteen patents recorded in connection with the artificial fuel question, but as a rule, many of them are merely repetitions of what has been enumerated before. One names nothing but tan and resin, which I should imagine might make a very good fire-lighter, although it is not included in that category. The only other worth referring to within the time I have just named is a peculiar treatment of peat, patented in 1850. The following is an abstract of the specification:—"Without previously drying the peat we treat it with waste by a mill in a way similar to that in which chalk is treated in the manufacture of whiting. The resulting liquor is made to pass through a strainer of wire work fine enough to prevent the passage of the large fibres into the tanks or backs cut in the earth, or built upon the surface of the ground if necessary, where it is left to deposit the finer parts of the peat. When this is effected the supernatant liquor is run off from the deposit, and the magma taken out from the tanks or backs and dried either by the air or sun, or on arches of bricks or other absorbent material heated by flues underneath."

In 1852, out of seven specifications relating to artificial fuels, I find one for dissolving peat in a chemical bath and then letting it dry; and another specifying one-twelfth of caustic lime, and one-twelfth of peat charcoal added to ten-twelfths of cut peat, mixed into a cement and moulded.

For the year 1853 I have selected two, out of a total of nine applications during that year. The first I give on the ground of its peculiarity, being composed of one-third of sea mud to two-thirds of sea-weed, and to 2,000 lbs. of this mixture is added 4 lbs. of nitrate of lead. Whether such ingredients would or would not make a decent fuel I am unable to say. The second specification for the same year shows how the same ingredients, that are now old to us, are still being used and in what proportions; but the patentee in this latter case goes in for moulding his mixture in various forms, and altogether departs from the usual antiquated brick form. During the same year we meet again with the small coal and tar business in the brick form, and in the specification I find a description of drying peat by heated revolving cylinders; while yet in another we have the treating of peat chemically while in the pugmill.

Out of a number of eight patents in 1854 for fuel there is not one of interest apart from what has already been shown, with the exception of one I may mention that is solely for the form or shape of any mixed or artificial fuel, the configuration being various, and having holes or passages through them for the purpose of better combustion.

In 1855 we number six patents.

A mixture for 1856 well shows the extremes that are adopted by different patentees in proportioning the ingredients: take here the enormus bulk of clay, 83 parts to coal 15 parts—to me rather an extraordinary proportion; if it was not we

should I think have heard more of it than what I am telling you now. There are nine patents for this year, but the one referred to is the only one worth notice, and that on account of its peculiarity.

During the year 1857 there is not anything worth mentioning, and in 1858 we get rye-flour as an ingredient. We again have ground peat mixed with tar.

In the year 1860 the number of patents fell to four, and the only one I shall notice gives equal portions of human or animal excrement, sawdust or chips, and small coal, and to this mixture add one-sixth part clay.

The most novel from the 1861 patents, of which there are five, relates to making boxes of wood about the size of a brick, then filling them with coal dust, and afterwards closing them up; in fact, it is enclosing a brick of coal in a wooden case, and then using it for fuel—a rather expensive method I should think of using timber as an ingredient.

In 1862 there are four patents for artificial fuel, but not anything of unusual interest.

The year following we again hear of seaweed treatment for fuel purposes. In one specification I find lime saturated with tar, which, after being used as a fuel, will, when ground, make a good cement, certainly a profitable way of dealing with the residue, especially if there is any real good in the fuel portion of the method. These two, out of five patents for 1863, are the only ones worth attention, with the exception that the last named process was duplicated by a subsequent patent a few months afterwards.

In 1864 we reach up to nine patents in connection with the subject, and one is peculiar in its ingredients. The patentee seems rather doubtful as to the proper relative proportions, for he names peroxide of manganese, 1 lb. to 10 lbs.; sulphate of lime, 5 to 50 per cent.; coal or coke, 100 lbs.; rosin and asphalt, 2 per cent.; oils, 7 to 12 per cent.; rosin or pitch, 12 to 20 per cent. In the remaining patents we have 90 parts of coal to 10 parts of cow dung twice over; we get also equal portions of peat and charcoal pressed together. The only other worth mentioning specifies cutting peat into blocks, putting them into an air-tight receiver, exhausting the air and moisture, and then admitting petroleum or any like substance.

I have placed one of the three 1865 patents among those worth notice as a novel composition; we have been in want of one lately, and I think this supplies the gap. We get 20 lbs. of meal to 3½ lbs. of pitch or tar, and 2½ lbs. of alum. It might make a very good fuel, but I am in doubt as to both supply and cost of the chief ingredients. One of the remaining patents treats only of the configuration of any fuel.

In the next year the number of patents doubles, but there are not any of interest with the exception of one I may mention, which gives to 1 ton of coal, 2 cwt. of sawdust, 40 gallons of tar, and 2½ cwt. of salt.

The year 1867 reaches ten patents on the subject, and all of them of what I may term the ordinary type. One is simply the coal and tar brick with holes pierced through as in 1864; another combines resin, glue, and salt with coal dust at a proportion of 50 lbs. of the mixture to the ton of coal.

In 1868 we again get ten patents on the same question, and I have selected two for the purpose of noticing the difference between the simple and the compound. In the first case we have 8 per cent. of coal tar to one ton of coal moulded into bricks. I suppose it is due to the simplicity of the idea of glueing small coal together with tar that we find it so often mentioned, but I wonder if the patentees could be aware of the age of the mixture at the time of securing their patents, when no doubt it was as common an article in fuel commerce as it ever has been. The second case gives very careful proportions of delicate ingredients, for, it is stated, to 17½ cwt. of coal dust and 2½ cwt. of clay, must be added 5 lbs. of rice, 5 lbs. of Indian meal, 5 lbs. of resin, and 20 lbs. of asphalt. I believe the smaller portions are admitted to gain the object of combustion with less smoke than ordinary fuel. In the same year we have two patents with the same ingredients and proportions as nearly corresponding as possible, viz., to 1 ton of duff add 2 cwt. of pitch and 2 cwt. of salt, and in the same year we again find turf saturated with oils or other like substances.

During 1869 out of six patents I may mention two of precisely the same treatment, viz., about 8 per cent. of rosin to coal, and another where carbolic acid is introduced in the proportion of 5 gallons to 1 ton of coal, together with 56 lbs. of pitch and 8 lbs. of salt.

In 1870 seven patents are recorded; as the date is nearing the present, I have taken three for the sake of comparison with former years. In the first we get the 10 per cent. of pitch, to 90 per cent. of coal and some sea weed, the proportion of which is not stated. The second is a compound of silicate of soda, salt, lime, and sulphuric acid, to which mixture 15 per cent. of coal is added. The third patent is certainly not novel, but suffices to trace the likness as we go on. We also hear in that year, of human excrement mixed with charcoal, of chalk with charcoal and pitch, and another arrangement of taking small coal and grinding it to a powder, and then mixing it with pitch or tar. We must bear in mind this is the year 1870; what the patentee's idea could have been respecting the cost of a fuel that required coal to be ground to powder, at a time when coal itself was at its lowest, seems strange; but even at the panic prices such a fuel could not, I think, have competed with coal; moreover, I cannot understand why the coal dust should be ground at all, let alone "to a powder."

We lower to five patents in the following year (1871), but I take two illustrations to show, in the one case the costly production, and in the other our old friend up again associated with a little food. As regards the first, to take 25 per cent. of creosote oil to 68 per cent. of coke, and add 5 per cent. of bituminous coal, and 2 per cent. of lime, cannot pay commercially, or compete with ordinary fuel. In the second we get our usual 1 ton of coal, to which is added 100 lbs. of pitch and 10 lbs. of farina, an ingredient we have met with before under another designation. I may remark before closing up this year of 1871, that we have mentioned in a specification a mixture of blood and lime with small coal.

For last year, 1872, I find nine patents recorded, and again of the stereotyped combinations. One patent 12 months ago is nearly similar to the patent of 1821. From this we may judge what progress has been made in the last 52 years, as regards artificial fuels of this particular class, and remember, of a class that has been found the most economical in production; possibly, too, the most efficient for the purpose for which it is required. It is needless to give farther trouble with abstracts of specifications; sufficient, I think, has been shown to illustrate a doubtful progress in the artificial fuel questions, and although we have had, subsequent to the last patent, and continue to have, applications for patents for artificial fuels, especially of late, there is not any thing new in them. Really some of the latest specifications read almost as copies of I may say, dozens that have appeared before.

In taking a retrospect of the various means of compounding an artificial fuel, the question arises, what material have we in quantity that is available for heat-producing purposes to anything like the extent required for relieving the draw upon the coal itself. I think we may assume that the coal residue is disposed of, or will be in the future, in a satisfactory manner, without those mixtures that appear on the diagrams more like "household receipts" than an article of consumption demanded in millions of tons annually. We have had in consideration sawdust, tanner's bark, asphalt, resin, and almost everything that will burn at all; but whatever use the whole or any part of these constituents, by addition, may serve towards making a good heat-producing fuel, it will be admitted that, for general purposes, even taking domestic consumption alone, the quantity collectively at command is anything but equal to the demand; and taking it for granted that certain admixtures will, laboratorily, give certain results in percentage of heat or work, it must be remembered that the requirement is a very great and a national one, and consequently any substitute for coal that may be introduced must be simple and not compound.

Combinations must naturally be expensive, if only from a mechanical point of view, whatever may be the value of the ingredients, even supposing we had quality; but while there is a query respecting quantity, coupled with the cost of quality, I think we can only arrive at the one conclusion, viz., take the most quantitative substitute, and at the same time the most simple, and see of what value it is, and how it can be dealt with to perfect it sufficiently to form a relief to coal.

The next, as compared with coal in quantity (putting quality on one side at present), is "Peat," the half brother to coal. For the sake of comparison, I will take the relative areas of coal and peat as generally estimated for Great Britain, viz., coal about 7,750,000 acres, and peat about 6,000,000 acres, and taking peat as averaging double the thickness of coal over the estimated area, we get 12,000,000 acres of peat as compared with 7,750,000 acres of

coal of the same thickness as peat; this is in bulk. Again, take peat in its condensed form as equalling one fifth of its average original bulk, we then get 2,500,000 acres of peat equal in density to coal, or say, one-third. It must be borne in mind, however, that coal has been worked to an extent quite different to peat, consequently we may infer that the present actual relative proportions between the two must be much more in favor of peat than these figures represent.

In passing, it will be as well to notice here why the question of manufacturing peat into a marketable fuel is of, I consider, great importance in more respects than one. In the first place it has the unequivocal advantage of being procurable upon the surface of the ground; and whatever may have been the difficulties heretofore, or even at present, as regards drainage, cutting, and general treatment of peat, it must be admitted that this one desideratum is strongly to be encouraged. Morally speaking, it is advisable to dwindle down as much as possible the extent of the almost inhuman labor below the surface compulsory for the production of coal—and labor that very few of those uninitiated could by any stretch of imagination anticipate, even excluding the risks that are in constant attendance upon such labor—and also take into consideration the ultimate result of the process upon the human intellect, as exemplified only too visibly of late, a result which gave rise at the moment to the controversy of how to economize an article of consumption that necessitated such uncivilized labor for its production. Of course, we know that the whole of this undesirable labor cannot be dispensed with at once, but we must confess that it is desirable to aim at such a purpose, and, by the utilization of peat and the introduction of coal-cutting machines below, we may soon anticipate a reduction in the extent of underground work.

Respecting the calorific power of peat, as compared with coal, I think we may safely assume that it reaches, in efficiently worked and well dried peat, an average of 75 per cent.; naturally the percentage varies considerably with different qualities of peat, some results being much higher and others much lower, but I think the above to be a fair average.

We next come to the question, "Why has peat been so little known generally as a valuable fuel, although staring us in the face by thousands upon thousands of acres in various parts of the country?" The answer is, that peat in its natural or raw state contains, according to the depth from surface and nature of deposit, a very great percentage of water, and it has been the disposing of this water that has proved the real difficulty in the way of producing peat as a fuel to at all compete with coal.

In referring back to the year 1800 we find peat mentioned in the list, but it is only stated as one of the ingredients of the mixture, and it does not specify how it is proposed to treat it so as to make it available for mixing; but in 1837 we have mention of "Operations for the purpose of converting peat moss and peat turf or bog into fuel." It is stated to be first cut up and then compressed and dried by artificial or other heats; and there are several methods named respecting the compression, such as hydraulic presses, levers, and screws.

We all know that for many years past machinery has been in operation for converting peat into a commercial or marketable fuel, and there are hundreds of tons of it being used; but still the question is, why only in hundreds of tons, when it ought to be, I may say, hundreds of thousands of tons? The answer is, as I said before, that the expenses incurred in trying to get rid of the water to an extent that will bring the specific gravity of the peat to something approaching that of coal, are so great, that it has been impossible to place it before the public in competition with coal in a commercial point of view, at the low prices coal has been standing at for years, until lately; and it is only in such cases as the late crisis that latent energy is wakened up for the purpose of seeing what can be done. I maintain that, let the price of coal come down to its own standard, or even lower, we must not lose the patent fuel question out of sight now that necessity has compelled us to grapple with it. We know how easily circumstances are allowed to fall into their normal state after an excitement is over; but this is a question of national importance, and now that it is proved that peat can be treated in a manner that will almost bring it down weight for weight in equal bulk with coal, and that it can be brought into the market at a much less cost than coal at its cheapest, I trust that we shall soon have it as common an

"household word" as coal, especially for domestic use. At the Dartmoor prison peat has for a long time performed every function required of coal; it warms the whole place and is also converted into gas for their own consumption, and all this is done with peat in a much more imperfect state than it can now be produced.

It may perhaps be interesting here to glance at the methods employed in treating peat, and the results obtained. I will again revert to its remarkable power of retaining water; when simply dried in the air, without any preparation, it will only part with about 70 per cent. of its moisture, no matter how long the exposure. If moderately cut up, or macerated, and then pressed and air-dried, it will still keep back about 20 per cent., and it must be borne in mind that the more the moisture retained, the less the calorific power of the peat; consequently, the drier the peat can be produced the greater the heating power. The great desideratum, therefore, is to get rid of the whole of the moisture, and if not all, as much of it as we possibly can. Artificial means of drying after compression have often been tried, but, even supposing that such a process resulted in a production as perfect as could be wished, the very fact of having to consume fuel to obtain the result, upsets all economical views of the case and thereby makes it too expensive for competition with coal.

To get peat to be universally adopted it is imperative that in the first place it must be freed from the whole of the moisture, or next door to it, for in a perfect condensed state it will give its greatest value in units of heat and take up the least stowage, which is very often a consideration; in the second place, it must be produced at a much less cost than ever coal can come to, otherwise it will never be of commercial value.

To gain these points there is only one way of getting at it, viz., thorough mastication or trituration of the raw material. I emphasize the word "thorough" for the reason that if the fibrous rooty portions of the peat are not cut up minutely, so as to release the water and air previously held fast by capillary attraction, you will never get rid of the moisture. Then after thorough mastication, simple exposure to the atmosphere for drying, and not artificial means. From the controversy on this question some time ago, it appears that this approach to perfection, if we may so call it, has only lately been accomplished by Clayton's machinery, which in my own judgment seems in design to be undoubtedly the best yet adapted for the special purpose, and certainly from the results obtained I think we may now hope speedily to see the thousands of acres of bog, now so much waste land, being made use of to an universal benefit.

The machinery in question accomplishes what has long been aimed at, not only in the mechanical treatment of the material, but I believe in cost of production as well; but as it is not the purport of this paper to subscribe or advocate any particular machinery or process for manufacturing either peat or other fuel, sufficient will have been said on that point.

The real object of this paper has been to glance rapidly through the past history of artificial fuels for the purpose of comparing with the present enthusiastic attempts that are being weekly brought to public notice through the patent lists as new, and to note what advance has been made; but if you take the trouble to peruse some of the latest, and very latest, specifications—and some of them are not very long—and then turn to the diagram list of 1799, you will find the same ingredients anticipated, although proportions may vary, which has been the case, more or less, ever since that date. I think, therefore, you will agree with me that as far as compound artificial fuels are concerned there has been no real advance, for to compare at all with coal it must be simple and in quantity.

The only advance of real good, seems to be the stride lately made in the manufacture of peat; and if the quality and marketable price only turns out what is promised, and I do not see any reason to doubt the good faith of it, I think we may congratulate ourselves and the community at large in having the question at last solved, of being able to procure a fuel in quantity and of a quality combining cleanliness in its purchasable form, together with a bright fire, less smoke, and still less residue during combustion.

In conclusion I will reiterate the hope that the time is not far distant when we shall see vast tracts of what is at present so much waste and useless country swarming with industry on the surface, which both physically and morally will be something towards alleviating the wretched labor at present required below the surface.

NOTES ON COPPER.*

From "The Mining Journal."

A mixture of metallic copper and sulphur, even at ordinary temperatures, will gradually combine, but far more rapidly on being heated, and will form sulphide of copper, or, as chemists term it, bi-sulphide of copper, in which for every 64 parts by weight of copper there are 16 by weight of sulphur.

If we take metallic copper, melt it, and keep it exposed to the air, oxide of copper is formed; but what is remarkable, the oxide of copper has the property of dissolving in the melted metal, and thereby changing its working qualities in a most remarkable degree. You cannot then hammer it either hot or cold; it breaks under the hammer, and the broken pieces show a color and character different from that of an ordinary ingot of copper. It has a red color, but verging towards purple, and there are none of those bright shining metallic grains which you see in a good piece of copper. There has been some difference of opinion as to the quantity of red oxide melted copper is capable of dissolving. From experiments made here some years ago, we found that in some cases the proportion might be 10 per cent of the oxide, and in some cases even more. When such copper is melted and ladled into an ordinary ingot mould, on cooling it will be found to have set with more or less of a furrow running down the middle of the ingot from end to end. The copper in this state is called in smelting works "dry copper;" it is quite unworkable. If now we have a quantity (say 8 tons) of the melted metal in a large furnace, if we cover the surface with small coal or charcoal, and leave it for some time, that will remove the oxide of copper, taking away the oxygen—that is, the oxide of copper will be reduced by the charcoal. To hasten the process it will be necessary to stir up the mass so as to bring more of the mass of metal into contact with the charcoal. The simple expedient for effecting this in copper works (refining works), is to take a long pole, about 15 ft. long, of green wood and plunge it into the midst of the mass of molten metal, and keep it there. The wood is rapidly charred; there is a great quantity of vapor evolved, and therefore, great ebullition or boiling takes place in the mass, and thus the copper is brought rapidly in contact with the overlying charcoal and the reduction of the oxide promoted. This operation is termed "poling." After the coal or charcoal has remained for a certain time, we will take out bits of metal to see what change has been effected, and test them by breaking them; and such a trial is made every time a mass of copper is refined. It is not required to take the red oxide wholly out; we shall find by means of the trial pieces, taken out time after time, that the metal becomes more and more tough, more hammerable, and at last, the refiner says, the copper has got its highest degree of toughness (he knows exactly from experience when this point is reached); at that moment the operation of "poling" is stopped, the pole is removed, and the copper is ladled out into ingot moulds. In this state it is said to be at "tough pitch," and it is moulded into more or less square cakes, and called "tough cape copper," suitable for the coppersmith; it can be hammered out and rolled perfectly. In the ingots formed by this copper we shall no longer find the furrow down the centre; it has set with a smooth face, and only a few cross wrinkles. If you try to break this copper with a hammer, you will not succeed, whereas a smart blow would readily break the "dry" copper. When the former is broken, on examining the surface of fracture, we shall see that the color is a characteristic fine salmon red; it will have broken with an even surface (in the former case with a rough surface), and we shall perceive in the centre what appear like small shining grains, but which really are small cavities broken across. It is usual to add to the metal before ladling into the moulds a certain quantity of lead—say, 14 lbs. to 8 tons of copper, though in some cases, when much foreign matter is present, as much as 80 lbs. are added; the lead making the copper set with better face, and more soundly.

Suppose, in the next place, we have kept the charcoal or coal too long on the molten copper, another kind of change will take place. When poured into an ingot mould we shall find it set with a ridge down the centre from end to end; it will again have

* From a lecture at The Royal School of Mines, by Dr. Percy.

become brittle and unworkable, and no longer hammerable. The color will have changed to a fine orange tint, and we shall observe tube-like cavities in the metal, as though some gas had escaped in the act of becoming solid; it will appear coarsely fibrous; the metal is said to be "over poled." There is considerable dispute as to the cause of this change. We made many experiments here some years ago on the subject. You must remember I am speaking to you of commercial copper, which is not perfectly pure; few men in the world have seen pure metals. In this operation of "poling" we must only proceed to a certain extent with regard to taking out the oxide of copper; if we destroy the whole of it, or reduce it to too low a percentage, we get "over-poled" copper. "Tough pitch" copper has 3 or 4 per cent. of red oxide in it, and it seems to be this red oxide which gives to the metal its workability or malleability. It has been said that "over-poled" copper contains a larger percentage of oxide than we found, but I believe our results were correct as far as they went. I have dwelt upon commercial copper. If we take chemically pure copper, and expose it to charcoal at high temperatures, we cannot "over-pole" it. Commercial copper contains certain foreign ingredients; the conclusion is that when these are present, to neutralize their effect upon the copper we must have a certain proportion of red oxide of copper in the mass.

In the year 1848 I had the honor of giving a lecture on the subject of copper smelting before the British Association at Swansea. I thought that I would prepare sundry specimens of copper, showing what would vitiate it. I got some "best selected" from the market, and melted it, and then I thought I would have some rolled, and so took it to a friend of mine at Birmingham for that purpose. To my astonishment, this quantity of metal, after being melted, would not roll at all, but cracked in all directions. I found that the addition of a certain quantity of various foreign ingredients, and notably a small quantity of phosphorus dropped into it, produced a perfectly workable metal. A small quantity of arsenic did very well, but I do not think anything gave a sounder ingot than a small piece of phosphorus. If we take pure copper, and melt it under certain conditions—*e. g.*, under a layer of charcoal—then we get a sound ingot, which will work admirably; or, still better, if we take this pure copper and cast it in an atmosphere of coal gas, which we can do by having a hole in each end of the cover of the ingot mould, letting the gas stream in at one end, and burn as it issues at the other, and then pouring the molten copper down in the middle of the flame, in this way we can get a magnificent ingot, or even by melting it under charcoal, and pouring it into a mould, taking care to let the molten metal come in contact with as little air as possible.

Perhaps it will have occurred to some of you that if the carbon or the charcoal united with the copper, as we know it does with iron, it might produce the effects of "over-poled" copper. I made some experiments at one time on this subject; I took some finely divided copper, and mixed it with a large quantity of charcoal, so large a quantity of charcoal in fact, that when I afterwards subjected the mixture to a temperature above the melting point of copper for a long time, the globules of melted metal could not fall down and form a layer at the bottom of the vessel, but would remain surrounded by carbon. If copper would combine with carbon, surely this is a condition in which the combination would take place. The pot was taken out of the fire, and allowed to cool, and then cast into an ingot; the ingot was most diligently searched for carbon, but not a particle could be discovered, so that we are warranted in believing that copper does not form a compound with carbon, and we cannot ascribe "over-poling" to the presence of that body in the metal.

An amount of phosphorus in copper equal to $\frac{1}{2}$ per cent. makes the metal wholly unworkable while hot; it becomes brittle or "red short," but it can be rolled when cold. The copper, by the addition of this small percentage of phosphorus, is greatly increased in strength. After I mentioned the fact many experiments were made at Woolwich on this phosphorized copper, in hope of adapting it to guns, but it was not successful. By increasing still more the proportion of phosphorus to about 1 per cent., they nearly double the tensile strength of the metal. If you take some of this copper from the market, melt it, and pour it into a closed ingot mould, on cooling it will shrink or contract; but the ordinary copper, instead of shrinking, expands or rises up. Here is a bell, cast of a specimen of copper

to the amount of 11 per cent.; it is a very hard metal, nearly white, but tarnishes rapidly in air; this bell gives a good clear sound, but not equal to that of the regular bell metal, which is an alloy of copper, with about 24 per cent. of tin. When I showed the specimens of phosphorized copper to Mr. James (now Sir H. James), then chief engineer at Portsmouth Dockyard, he asked me to let him try the effects of sea water on them, and he found that of all the specimens, that containing the most phosphorus was least acted on. Thereupon he made an application to the Lords of the Admiralty for experiments to be tried on a larger scale, which was granted, and I procured further specimens for him. In the course of the preparation they came to me, and said they could not roll the copper when hot, but at ordinary temperatures it rolled perfectly. Two buoys were covered, one with phosphorized and one with ordinary copper, and although, through some mistake, they were painted, still it was found that the former was not acted on by the sea water so readily as the other. Here are specimens of phosphorized metals from the International Exhibition of last year, said to be of gun metal, with a certain proportion of phosphorus, said to have greater hardness and greater strength than bronze, and can be used for cutting instruments, for pistols, etc., and are especially adapted for use in gunpowder works. Mr. Abel found that to get perfectly sound castings of phosphorized copper it was necessary to use a metal mould; sand would not do.

The presence of impurities in copper interferes with its power for conducting electricity; the conducting power of pure copper being 93, an addition of a small quantity of phosphorus brings it down to 7 or 10. A small quantity of arsenic dropped into melted copper has the same effect on the workability of the metal as phosphorus; every specimen of copper occurring in commerce contains traces of arsenic, and sometimes more than traces; in some specimens of Spanish copper as much as 2 per cent. Silica or sand is a compound of an element like a metal called silicon and oxygen; this silica has the property of combining with iron, and giving certain qualities to it; it is an almost invariable constituent in pig iron. If you take common sand, and mix it with finely powdered metallic copper and charcoal, expose it to a high temperature so as to melt the copper, and the other constituents being present in such large proportions as to prevent the molten metal from sinking down and forming a layer at the bottom, the charcoal lays hold of the oxygen of the silica, and the silicon enters into combination with the copper. Here are specimens containing 2 per cent. of silicon; the compound is very tough, can be cast, and cast perfectly. If we have more silicon than this present, we get a white, brittle, good for nothing metal.

COLMATION.

By J. P. FRIZELL, C. E.

Readers who have a fancy for examining the reports of the United States Engineer Department, have doubtless noticed in the volume for 1869, certain communications addressed to the Secretary of War by Gen. B. S. Roberts, suggesting a plan for ameliorating the condition of the Lower Mississippi Valley.

This plan, stated in language rather more figurative and elevated than is usually looked for in the discussion of a purely technical subject, amounted to this:—

He would draw off the flood waters of the river through suitable sluices and weirs in the embankments, and allow them to deposit their sediment upon the low grounds subject to overflow. He looked for several advantages from the adoption of this plan; mainly the elevation of the swampy grounds to such a height as to insure a suitable drainage; incidentally the improvement of navigation over the bar at the mouth of the river, consequent upon the diminished amount of sediment. He also proposed the introduction of water from the great lakes to raise the low-water stage of the river. The same volume contains a report upon the subject from Gen. A. A. Humphreys, the present chief of the engineer department, to whom the paper was referred. He details the result of a computation based upon the quantity of sediment contained in the flood waters of the Missisippi River, as ascertained in the course of the Delta Survey, show-

ing that, under the most favorable suppositions as to duration of floods and quantity of sediment, it would require 150 years to raise the St Francis Bottom, a region 6,000 square miles in extent, one foot. He concludes with the observation: "Having thus shown the impracticability of attaining the ends proposed by Gen. Roberts, I trust I may be excused from presenting a view of the cost necessary to carry out his plans."

The application of this system to the entire alluvial region would, so far as its cultivation is concerned, amount, as Gen. Humphreys observes, to a restoration of the country to its normal condition. The levees would be of little use if the country was subjected to inundation at every flood. It by no means follows, however, that the system could not be applied with advantage to less extended districts. In such application the arrangement suggested by common foresight would be, to allow the water to flow, with a very low velocity, over the ground to be benefited; every one familiar with the subject knows how rapidly deposits accumulate under such conditions.

In closing an island chute, the most approved method is to build a low dam across the upper or lower end, preferably the lower, allowing the water to flow over it, thus checking the velocity and leading to a rapid accumulation of deposit. The height of the dam is increased as the shoaling progresses. At first the channel receives the coarse material rolling or sliding on the bottom. As the dam is raised and the velocity diminished it takes only the fine material held in suspension. I remember, when engaged upon the Des Moines Rapids Steamboat Canal on the Missisippi River, that a cofferdam for one of the locks was flooded in the early part of the season, and remained so nearly all summer, the water flowing 2 or 3 ft. deep over the upstream wall of the dam, and, of course, taking a very low velocity within the enclosed space. When the dam was pumped out, there was a deposit of fully one foot in depth over the greater part of the bottom.

The entire Mississippi delta consists of material deposited by running waters. It is but natural to suppose that some artificial control might be advantageously exercised over an agency capable of such stupendous results.

It is not the purpose of this article, however, to advocate or oppose the views put forth by Gen. Roberts. The really noteworthy feature of the correspondence alluded to, is, that both parties treat the subject upon purely speculative grounds. Gen. Roberts appears to suppose himself the inventor of the system, and Gen. Humphreys opposes the project by theoretical calculations and reference to other theoretical calculations contained in his book. The discussion is incomplete, inasmuch as neither party cites any existing application of these principles. In discussing so important a matter, it is always proper to inquire as to the past experience of mankind. This is what I propose in what follows.

The process of raising the level of lands by artificially distributed alluvion, is designated in the French language by the word *colmatage*, in German by *colmationen*. I have not met with any English equivalent of these terms, probably because the practice does not exist in English-speaking countries. We may, perhaps, following a natural analogy, introduce the word "colmation," forming the caption of this paper.

I take the following general description of the process, as practised in France, from Buffon:*

"It now remains to speak of *colmatage*, which is at once the most simple, the most powerful, and the most economical of the processes of drainage, especially upon swampy bottoms. The necessary conditions, however, are by no means everywhere present; it is for this reason that the process has thus far been restricted to a small number of localities, where it has been employed with very great advantage.

"Colmation is nothing more than filling, successively effected by means of artificially distributed alluvion, and where a sufficiently abundant volume of turbid water is available, it is attended with results generally surpassing expectation. We shall see in the following section, in treating of irrigation, that *limonage*, or the employment of winter waters, with the simple aim of fertilizing, without seeking to change the level, is a very energetic operation, in the sense that, if we compute in cubic metres the contents of the lightest layer deposited by ordinary water, upon the extent of a hectare, we shall have a considerable result, which well illustrates the effects of this potent amelioration.

"When considerable depths are to be

* Cours d'agriculture et d'hydraulique agricole. Paris, 1855. V. 2, p. 261.

covered, the colmation of marshes and swampy bottoms may profitably employ torrential waters, drifting gravel and pebbles.

"To attain the best results, it is in the order of things that we should commence to fill the deeper parts with coarse materials, very permeable, in order to imitate as far as possible the march of nature in the formation of alluvions, which are always the best agricultural grounds. If we have no torrential waters at our disposal, from which to extract deposits of this nature, we must content ourselves with the employment of those which deposit only mud or sand, and grounds formed to a certain depth with these latter elements, are always of high price, as proper for all sorts of cultivation.

"The processes employed for colmation are extremely simple; they consist in opening upon the shore of a rapid stream, subject to great floods, a species of cuts, called *epanchoirs*, by means of which volumes of water, approximately regulated, are directed, by special canals, upon the bottoms to be raised. The waters retained and becoming stagnant upon the bottoms, then deposit the sediment held in suspension; and, some time after their introduction, they are carefully drawn off, partially or totally pure, to be replaced by a fresh supply. The rapidity of the process depends upon the percentage of suspended matter and the frequency of renewal.

"The mechanism of the operation is thus very simple; it consists solely in the introduction of turbid waters by the aid of feeders, of declivity as near as possible equal to that of the supplying watercourse, then in a slow and superficial system of overflow, withdrawing the water freed as far as possible from sediment. This latter flow takes place usually by the aid of wooden weirs, roughly constructed, the height of which may be successively diminished. Dams provided with stop-plank are most convenient. The essentially temporary character of these structures enables us to avoid masonry. In most cases structures of rough wood are found to answer the purpose.

"A great extent of shallow ponds and low levels or salt marsh, bordering upon the Mediterranean, in the departments of the Ande, of the Herault, and the mouths of the Rhone, have been colmated in this manner, and are to-day meadows of the first quality; others are susceptible of the same improvement.

"An intelligent use of waters very rich in sedimentary matters, like those, for instance, of the Ande, the Herault, the Orbe, the Durance, etc., readily leads to a deposit of 15 or 20 centimetres (6 or 8 in.) in a season. * * *

"The waters of the Durance are peculiarly proper for colmation. It is a well established fact that the plains of Caraillon and others, which are abundantly overflowed by these waters, nearly always turbid, are successively raised; but excellent operations of colmation, properly so called, are now made by conducting the waters of the canals of the Durance, notably those of the territory of Avignon, upon the arid and gravelly plains, which, by a defect opposed to that presented in marshes, are equally sterile.

"Enclosures of an area proportioned to the disposable volume of water, being formed by low dikes, as if for simple irrigation; a slow and successive overflow favorable to sedimentation,—such is the method employed for this artificial creation of soil suitable for gardening and all improved processes of cultivation. In this case the materials brought into use being but earthy substance, without mixture of gravel or pebbles, the velocity being moderated in the canals of supply, which were constructed originally for simple irrigation, they obtain ordinarily a deposit of 3 to 5 centimetres (1 or 2 in.) per season; this, however, is a very gratifying result considering the increase of value; that is to say, considering the possibility of creating, in two or three years, an additional value of more than 1,000 francs per hectare upon strands or wastes formerly almost worthless. Frequent reference is made to the operations of colmation, executed upon these principles, in the vicinity of Avignon, by M. Thomas, a rich manufacturer and proprietor, who has already acquired in this manner a great extent of excellent soil.

"The operation of colmation should therefore be indicated, among the studies of the hydraulic engineer, as one of the most efficacious methods of applying the action of water to the improvement of agriculture."

It is in Italy, however, that this system has attained its greatest development and accomplished its grandest results. I take the following facts mainly from Hagen,* who appears to have studied this subject with great care.

The Chiana valley is an exceedingly level

* Wasserbaukunst, 1st part, vol. 1, p 355.

tract, some 30 miles in length, uniting the water systems of the Arno and the Tiber. Ancient writers affirm that the Arno once separated itself into two parts at the northern extremity of this valley, near Arezzo, one branch flowing southward, through the valley, to the Tiber, the other pursuing its present course, thus forming a navigable channel between Rome and Florence.* This is, however, a debated question among hydraulicians. Tacitus† relates that a project was introduced into the senate to separate the Clanis (now Chiana) from the Tiber, and turn it into the Arno, in order to moderate the floods of the former river, but that it was given up at the remonstrance of the residents of Florence. Later, however, though at what date is not clear, the separation was actually accomplished, and the waters of the Chiana were turned into the Arno. It appears, moreover, that the residents of the Arno valley, to protect themselves, also built a dam, about 40 ft. high, across the extremity of the Chiana valley. By these works the whole valley of the Chiana was reduced to an utterly uninhabitable condition. Its malariousness became a proverb in Italian literature, and when Dante aad other writers would stimulate the imaginations of their readers to conceive of a very pestilent place, they would compare it to the Chiana valley.

During the reign of the Medici, public attention was strongly directed to this unfortunate region. A map of the valley was prepared by direction of Julius of Medici (later Clemens VII.), in the year 1551. Hagen gives a copy of this map upon a reduced scale, from which it appears that the dam on the Arno side had prevailed over the other, the summit of the valley being, apparently, near the former. Torricelli, who studied this case, reported that the only available method of improvement would consist in raising the ground by sedimentary deposits, the feasibility of which process had, as it is presumed, been already pointed out by nature.

No action was taken, however, till the latter part of the last century, when the work was undertaken in accordance with a project prepared by Fossombroni.‡ The former condition had, however, materially changed.

Since 1551 the ground had been raised in some places 37 ft. (Prussian). The details of Fossombroni's plan, by which it was expected to raise the level of the valley so that its drainage could be effected through the sluices of the dam at Arezzo, were as follows:

The small streams leading into the Chiana valley were provided with dikes. Embanked canals conveyed the water through the districts to be raised, where it was received in basins formed by low dikes. These basins usually had an area 100 to 300 times the square of the breadth of the river furnishing the supply. Often, several of these basins lay in succession, the water flowing from one to the other. The wasteways and weirs consisted of depressions in the embankments, protected by fascines.

Ordinarily the dikes were raised to full height, that is, some 2½ ft. above the required level of the ground. The lower grounds, hower, were raised by successive stages. It was, in some cases, found necessary to divide the basins by cross dikes, to moderate the force of the waves. Narrow sluices of timber were provided, through which the water could be drawn off, when freed from its sediment, into canals at a lower level. These sluices were closed by stop plank which were successively removed, thus drawing the water always from the surface. This work was carried on directly by the Government. In 1823 it had progressed so far that the malarious character of the valley had entirely disappeared, and extensive settlements had been formed. There remained, at that time, about 160 square English miles to be reclaimed. Of the original area of the morass I can find no statement.

The streams made use of in this work, being of a torrential character, were better suited to this purpose than the Mississippi in one respect, viz., containing a larger percentage of sediment. In another respect they were less suitable; the duration of the floods never exceeding three days.

Other similar works have been executed in Italy inferior in extent to this, viz., the Pontine Marshes between Rome and Naples, and the Bonificamenta of the Maremma, where it is said that an area of 40 square miles has been covered with a deposit of earth 2 ft. in thickness.

* Extrait des recherches sur le systeme hydraulique de l'Italie par M.de Provy. Annales des Ponts et Chaussées. 1834. II. p. 384.

† Annalium, liber I.

‡ Memoire idraulico storiche sopra la valdi Chiana. in the Raccolta d'autori Italiana che trattano del moto dell' acque, 1789.

ON THE MANUFACTURE OF STEEL.

From "The Engineer."

At a recent meeting of the Society of Arts, Sir Francis Charles Knowles read a paper on the "Conversion of Cast Iron into Steel," and the exhaustive and suggestive nature of this paper, as well as the discussion which it induced, are such as to make us feel that a *resumé* of the important question thus investigated and analyzed will be acceptable to many of our readers. Indeed, the subject in its broadest and fullest sense, viz., the means of converting iron into steel, is one which, like good wine, requires no bush. It is of the first importance to the nation, whether looked upon merely from a commercial point of view, as giving us the power of being the great manufacturers for the world, or in the higher and more recondite sense of enabling us through the researches of science to avoid waste in the development and utilization of the great natural, mineral, and other resources placed at our disposal.

It seems desirable for the purposes of the present article to take the questions in the order in which they are treated by Sir Francis, and to comment upon them and his remarks as we proceed, reserving the discussion which followed, with the expression of our own opinions for the final summing up. We do not understand from the paper before us that the process advocated by Sir Francis has been actually tried, even in experiment, and we must confess that the way in which he uses the present tense through a great portion of his paper is somewhat puzzling, if not disingenuous; for, although, of course, the Heaton process is sufficiently well known, it does not in many ways exactly correspond with that now brought forward, and whilst Sir Francis says that "the finery or converter is made of pieces of cast metal so constructed that the tuyeres may form one piece with the casting itself—in fact, they are bored out of the solid casting itself, and the apertures are countersunk to meet them at the level of the hearth, etc."—we fail, nevertheless, to gather from the general context of the paper, or any definitely recorded results given, that such a finery or converter has actually been made and tried, and hence that both the author in explaining, and we ourselves in examining, the process, are dealing with possible probability rather than with ascertained fact. However, on this point we are indisposed to take exception, not that we think from what we have read that such exception is not a just one, but because we are desirous that, if the theories propounded have not as yet been proved, no words of ours may in any way stand in the way of their thorough investigation by practical experiment.

The objects proposed to himself by our author are, broadly speaking and in his own words, "the refining or purification of cast iron from sulphur and phosphorus, and its conversion into iron or steel of various qualities, according to the nature of the metal treated, with an increased yield of malleable iron or steel per ton of metal." And he goes on to say that the means adopted are—here again is a case of the present tense:—(1) "The separation, as far as possible, of the heating process from the chemical process. (2) The securing of a highly basic scoria, or cinder, of not exceeding 30 per cent. of silica, by means of finery and converting furnace in which that acid is not present. (3) The employment of caustic soda, in conjunction with pure and rich oxide of iron, in the elimination of the sulphur and of the phosphorus. (4) Where pure cast iron is treated, and superior steel is to be produced, the use of nitrate of soda, of permanganate of soda."

It is evident that to carry out any of the above processes, and to obtain any of the proposed results, heat is necessary; and this it is intended should be produced by the complete combustion of gases rich in carbonic oxide gas combined with air heated to 500 deg. Cent. in due porportions; and to this end, when the metal is melted in a cupola with either dense coke or anthracite coal, the resulting gases are collected and utilized by freeing them from carbonic acid and feeding them with pure carbonic oxide gas until a compound be obtained consisting of 70 to 80 per cent. of carbonic oxide gas and 30 to 20 per cent. of nitrogen. From this gas, which may be slightly altered in composition, a heat in combustion of from 2,500 deg. Cent. to 2,979 deg. Cent., is obtainable, and on its being mixed in the condenser with hot air in such proportions

as to insure the production by combustion of only carbonic acid gas and nitrogen, without excess of air, it is blown, according to Sir Francis Knowles, "into the body of the metal bath by appropriate apertures at the level of the hearth or sole, giving, therefore, a neutral flame, while the carbonic acid gas and the nitrogen rising from below with force in all directions, and aided by the natural lightness of the hotter metal, stir, agitate, and mix the particles of the metal, and so bring them all successively into contact with the re-agents employed, and with each other, doing in fact the work of the puddler." So far so good; but one of the most remarkable features of the new process follows next, for it is further proposed that the carbonic acid gas that is thus formed and the nitrogen which quits the surface of the ball, at say 2,150 deg. Cent., shall be passed through a kiln holding anthracite coal or coke, when the gas will take up a second equivalent of carbon; and one volume of it will yield two volumes of carbonic oxide, which absorbs about 2,400 units of heat per 2⅓ lbs. of weight, the nitrogen remaining unaltered; and if, after a second combustion, this conversion of carbonic acid into carbonic oxide be repeated, the proportion of carbonic oxide to nitrogen will fall to 39.71 per cent., and so on in a decreasing ratio, until 34 per cent., the proportion in the cupola gas, is reached. The carbonic acid is thus acting as a carrier of the fuel from the retort of anthracite coal or coke to its destination, and the converted gases may be used first to heat the generating retorts and then passed under the boilers, which, according to Sir F. C. Knowles, ought, with good management, to be heated without any other fuel.

We now come to the construction of the finery itself, which, as has been before stated, is made of cast iron, the tuyeres being bored out of the casting itself, and the whole bound together by an exterior jacket of boiler plate, so that in case of an accidental fracture there may be no danger from the access of water to the molten metal, the whole converter being inclosed in a tank through which are passed currents of cold water to prevent fusion of the sole or walls of the finery.

For the lining of this, a basic paste is formed of protoxide of iron, or of manganese, of naxos emery, or of bauxite, a silicate of aluminum, strongly recommended by Dr. Siemens as fettling for his rotary furnace, and caustic soda in small quantity. This paste is laid on in thin layers, which, when gently dried, are successively reduced to a state of incipient fusion by the flames of the gases in such a manner that the particles may cohere and form a species of semi-enamel or glazing. The furnace is then complete and ready for operation. The next points for consideration are the effects of the reagents—caustic soda and the oxides of iron and manganese, which, as entirely distinct questions, we reserve for the present. We have stated enough to show what the general nature of the scheme is, and that it claims much about which opinions will differ materially.

THE STABILITY OF IRON STRUCTURES.

By W. MATTIEU WILLIAMS, F. R. A. S., F. C. S.

From "Iron."

A great deal has been written and spoken concerning the molecular changes produced in iron by vibration, and many instances are cited of iron that has shown a crystalline fracture after long exposure to vibratory disturbance. But those who theorize upon the so called molecular changes due to such action, base all their conclusions on a few exceptional facts, and apparently forget the multitude of other facts which contradict their theory. Ordinary experience shows that good iron remains fibrous throughout its substance after years, and even centuries, of considerable vibratory wear and tear. This broad general fact throws much suspicion on the isolated cases of crystalline structure attributed to vibration. If vibration is a true cause of crystalline structure, then crystalline structure should follow as an invariable consequence of vibration. This is certainly not the case, and therefore where the crystalline structure has been occasionally found we should look for another cause. This, I think, is not difficult to find, viz., in the original bad iron. It is no reply to this to point to the fact that one part of the piece of iron in question was fibrous, and the other portion

that is supposed to have suffered, or really may have suffered more vibration, was crystalline, because, as every practical iron-worker knows, we may find fibrous and crystalline iron, not merely in different fractures of the same bar, but even in different portions of the same fracture. Inferior, ill-worked iron is especially liable to such irregularities of structure. The theory that localized crystalline structure is produced by vibratory action may sometimes be very convenient for contractors, but I doubt whether it has any reliable foundation in fact.

The above remarks must not be understood as implying that vibratory shocks may not weaken iron. There are many incontestable facts which prove that a vibratory shock, if sufficiently violent, certainly does affect such weakening. I need only refer again to the trials of armor bolts by the falling test, described in my last paper. Here we had a definite force applied as a sudden shock, a weight of one ton falling 30 ft. The first blow is resisted by the best iron, the second blow also, likewise the third; but, on applying the same amount of force in the same manner a fourth time, the iron yields, showing that the previous shocks had weakened it, and rendered it unable to resist a blow that it was previously able to bear.

But was this weakening due to the development of crystalline structure? Certainly not. The alteration of structure indicated by the best iron was rather in the opposite direction. The "distress" exhibited after the first blow, and more and more obviously displayed after the second and third, presented the appearance of a dragging or stretching out of the fibres, a sort of exaggeration of the normal fibrous structure of the iron. In those parts where the extension and consequent reduction of diameter was the greatest, the fibrous structure of the iron was to a certain extent visible on the skin of the metal, and the final fracture of the best samples had a brush-like character, due to this dragging out or exaggeration of fibre. These appearances are also observable when the best iron is broken by a gradually applied tensile strain, and may be studied in some beautiful samples of fracture that are preserved by Mr. Fairbairn.

It is true that in these cases the strain has been exerted only in one direction, and doubtless the effect would have been different had its direction varied, but what would be the extent of this difference? Merely, I suspect, to neutralize the dragging out or exaggeration of fibre, but not to substitute for this another and very different action—viz., the development of crystalline structure. I do not at all question the conclusion that a long continuance of small vibratory shocks may probably weaken iron or steel by gradually effecting a similar "distress" to that so plainly exhibited and suddenly produced by the violent shock of the falling test, but do maintain that we have no sufficient or even approximately sufficient evidence in support of the theory that vibration can convert fibrous into what is called crystalline iron.

A further and full experimental investigation of this subject is imperatively demanded, and may readily be made. Cut a good plate or bar into at least twenty equal pieces; shuffle them well, then take ten and ten. Let the first ten be laid aside in a quiet place, and the other be exposed to continuous and sharp vibration for a year or two. Attaching them to a tilt-hammer regularly used for shingling the faggots of blistered steel, and making about 300 strokes per minute, would do very well for this purpose. Then let each two be tested for tenacity and their average tenacity compared.

I say at least twenty, because all wrought iron is more or less variable in cohesive power at different parts of the same plate or bar, and thus the more numerous the trials and broader the average, the more reliable the result; and "shuffled," because if one set were all middle pieces, and the other all side or end pieces of the plate or bar, the trial would be delusive.

There is another and very curious question connected with this subject that also demands similar investigation, its practical and philosophical interest being considerable. It is whether iron and other inanimate substances are susceptible of becoming weakened by "fatigue," and of recovering in some measure by repose. Many may smile at the bare suggestion of such a question, but it is not so ridiculous as it may appear. Intelligent workmen, whose daily experience constitutes the broadest of experimental data, assert that the tilt-hammers of steel works, which work with the greatest rapidity, rapidly give way near the axis unless they are allowed intervals of

rest. I have never had an opportunity of verifying this or any other similar cases, but, nevertheless, see no good reason for discrediting it, nor any great difficulty in understanding how it may occur. When iron, steel, or any other elastic substance is subjected to a gradually increasing strain, the first indication of distress is an elastic extension, that is an extension which is partly or wholly recovered when the straining force is removed. Now let us suppose that the total breaking force in any such case is $=a+b$, where a is the amount of force sufficient to produce an elongation recoverable by elasticity; it is evident that when the substance is in this condition, the strain by which it may be broken is a smaller force than when, in its normal state, it is b instead of $a+b$, or otherwise it is weaker in this condition than when at rest. If, then, the recovery from the state of elastic strain is not instantaneous, but demands some time, a period of rest equal to that time is demanded, in order that the strained material may recover from its fatigue. The question is thus reduced to whether complete recovery by elasticity is instantaneous or occupies some time, and how great is that time? Also whether this period of recovery varies with different substances? There can, I think, be little doubt that an appreciable time is demanded, that the length of that time varies considerably, and is intimately connected with that internal friction which has been described as molecular viscosity.

The effect of temperature on the stability of iron and steel has been recently treated rather fully in iron. Putting all the reliable experiments and other data together, I think I may venture to generalize to the extent of saying that lowering of the temperature of iron or steel affects its powers of mechanical resistance in nearly the same manner as the addition of carbon, silicon, or phosphorus, the resemblance being nearest to the action of phosphorus.

If this is correct, then the effect of intense cold on iron or steel will be to increase its brittleness when subject to a vibratory shock, while it increases its tenacity as tested by a gradually applied and steadily increasing strain, and the effect of raising its temperature is the converse of this, *i. e.*, a given sample of iron will be less liable to fracture by mere vibration when hot than when cold, and weaker when tested by a steady pull. I may also venture to express my belief that the presence of sulphur, within certain limits, tends to mask this difference, but not to fully counteract it, while phosphorus, silicon, and carbon materially exaggerate it. Or, in other words, sulphur diminishes the differences due to a given variation of temperature, while phosphorus, silicon, and carbon increase it.

Those who have studied this subject and are disposed to prosecute it further, will, I think, find in the above inductions an explanation and reconciliation of most of the apparent contradictions which recorded experiments present.

ARCHITECTURE IN THE ELEVENTH CENTURY.*

By J. H. PARKER, C. B.

From "The Architect."

In two very interesting old churches that the Institute visited in the course of the year 1872—St. Mary's, Guildford, and St. Michael's, Southampton—the same remarkable feature was observed which had previously escaped observation—the remains of a small cruciform church enclosed and incorporated in a much larger church of a later period. This sort of economy is very usual in old parish churches, the people preserved as much as they could of the small old church when a larger one was required. The question naturally arose as to what period these two old churches belonged; I considered them as more probably of the first half of the eleventh century than of any earlier period.

In the account that I wrote of St. Mary's, Guildford, I stated that opinion; and gave, as my reason for thinking so, that the generality of the so-called Anglo-Saxon buildings are of the eleventh century, and that there is a wide distinction between those of the first half and those of the second half of that century; during the

* From the last number of the "Transactions of the Archæological Institute."

second half we know that the Norman style came in, but it was not imported as a complete style from Normandy, it was gradually developed after the time of the Conquest, both in England and Normandy (which had then become only one of the provinces of the same kingdom), and the style is properly called by the French antiquaries the *Anglo-Norman* style. Normandy was a little in advance of England as regards architecture at the time of the Conquest, but not much; the Anglo-Saxon buildings had greatly improved in construction before the time of the Conquest, and the Norman style had been introduced at Westminster by Edward the Confessor. During the reign of that king we have also the dated example of Deerhurst, A. D. 1053, the construction and decorations of which are very much in advance of the Anglo-Saxon towers of Lincolnshire and the Dane's land, which belong chiefly to the reign of Cnut, or Canute the Dane. These towers are more common than people are generally aware of; Mr. Matthew Bloxam and myself made out and published a list of a hundred of them twenty or thirty years ago, and many more have been observed since that time by Sir Charles Anderson and others. They belong to the churches recorded to have been built by order of Canute on the sites where churches had been burnt by his father or himself during the wars which ended in the settlement of the Danes on the eastern side of England. All this is a very old story, but it seems necessary to recapitulate it, and this brings us clearly to the first half of the eleventh century. My own conviction is that the churches that had been burnt by the Danes were wooden churches, and that the churches built in their places were of "stone and lime," as is recorded in one instance certainly, that of Assandun (Ashington, in Essex). Stone buildings were then becoming more the fashion, there always had been a few, but they were the exception; the general custom was to build of wood as most economical, the country being to a great extent covered with forests.

The question now disputed is, whether these churches were built by persons accustomed to build of cut stone, and were only a continuation of the debased Roman style of building and of construction, or were built by persons accustomed to build of wood only, and are rude and clumsy imitations of Roman remains?

In all probability the greater part of the buildings recorded to have been built of stone in the tenth century, were built of rough stone or rubble—walling only, and not of cut stone. The few buildings that were of cut stone were so very remarkable that they were always recorded and eulogized to a degree that seemed absurd afterwards, but they were so superior to anything the writers had then seen, that they made the most magniloquent description of them. We all know the description in Latin verse of Winchester Cathedral, as built in 980, and yet we also know that a century afterwards it was swept away as not worth preserving; even in the building erected in its place on a new site the construction of the early part is very rude; there is a great waste of material and of labor; the joints between the stones are extremely wide, and the contrast between this construction and the later work of the twelfth century, after the fall of the central tower, is one of our best guides to the distinction between the construction of the eleventh and of the twelfth centuries. If even quite at the end of the eleventh century the masonry was not further advanced than that, we may well imagine how rude the masonry must have been three generations before that period. Those three generations were a time of rapid progress in the art of building, and this therefore carries us back to the rude construction of those Anglo-Saxon towers, and to the herringbone work in the walls, which is one of the characteristics of that period. All the dated examples of herringbone work that I know of are of the first half of the eleventh century, and I know of several of that period in various parts of the world. There is one in Rome, dated by an inscription upon it (the side wall of St. Pudentiana), another in Normandy, dated historically, that of the castle of Plessis, and there are others in England also.

It has long been seen and acknowledged that very often the only mode of distinguishing between the construction of the eleventh century and that of the twelfth is by the thickness of the mortar between the joints of the stones. This is well exemplified in the two great abbey churches of Caen as well as in Winchester Cathedral. The construction of the first half of the eleventh century is so bad that it is evidently an imitation of the much better construction of an earlier period. The small

old church at Bradford, in Wiltshire, is just one that proves my point: the construction is extremely good, such as we do not find anywhere in England or France in the tenth or eleventh century. The joints are as fine as possible, which they never are anywhere in the eleventh century. If the Roman art of building was not lost at least for one generation of men, how does it happen that the art of vaulting (a very important part of Roman architecture) was entirely lost, and no builder ventured to throw a vault over a space of 20 ft. wide before the middle of the twelfth century? The general use of wooden buildings in the period between the Roman empire and the twelfth century is the only manner of explaining this. Wide-jointed masonry is always one proof of bad and clumsy construction. The Anglo-Saxon towers of the first half of the eleventh century are evidently the work of carpenters only, of men not accustomed to build of cut stone. No mason would think of placing long pieces of stone vertically up the angles of a tower and make a framework to bind it together. Jarrow and Monks Wearmouth support my view. The monk of Durham of the time of William I. and II. distinctly says that these churches were in ruins, and overgrown with shrubs, when they were restored by his brother-monks, and the existing remains agree perfectly with this history.

Bradford stands in the middle of some of the best stone quarries in England; it was therefore cheaper to build of stone there in the eighth century. But the greater part of the country was covered with forests, and therefore wood was the natural material to use in most places. This building was exceptional. My much-lamented friend, M. de Caumont, of Caen, was certainly one of the best, if not the best archæologist of France, for the last 30 years. He was the first to introduce the principles, though not the details, of Rickman's system into France, about 1830; and to form an Archæological Society, to make excursions to objects of interest in all parts of France, and to compare one province with another. He and his companions found, by long and frequent observation, that the very distinct provincial character of the different parts of ancient Gaul can all be traced to some one Roman building, which has served as a type for that district, when the revival of building in stone took place. The best known instance of this is the diocese of Lyons, where fluted columns, in evident imitation of their Roman type, are used in the cathedral in a construction of the thirteenth century, and the same thing occurs in many other churches of that diocese.

For many years past I have been hunting for buildings of the tenth century with very little success. It is matter of history that some stone buildings were erected at that time, but there is very little construction of that period remaining in any of them. I have been a member of the Société Archæologique de France for the last 30 years, and made many similar researches with them. M. de Caumont himself went with some friends to the sites of all the castles of the Norman barons who came over to England with William the Conqueror, to search for examples of the masonry of that period. To his great surprise and annoyance, he could find no masonry at all in any one of them before the time of the Conquest. He found magnificent earthworks in all of them, but no masonry; showing that the castles of the first half of the eleventh century were of earthwork and wood only in Normandy, where, of all other places, we should have expected them to have been of stone. The Normans were certainly not behind the rest of Europe in the art of building. Even in Italy it is very difficult to find any masonry of the tenth century now remaining. In Rome the only building of that century is the sacristy of the church of Sta. Croce, in Gerusalemme, which is dated by an inscription upon it. The construction of this is as bad as it could be; a worse construction would not have stood at all. Of the first half of the eleventh century in Rome, the only dated example is the wall of the church of St. Pudentiana, and the construction of that is of herring-bone work. It happens also, that all the other dated examples of that construction that I know of, are also of the eleventh century, but such simple construction may be of any period. In the celebrated example of St. Remi, at Rheims, the construction of the walls is of the character of the first half of the eleventh century, but all the ornamentation has been added or entirely altered in the twelfth. Some, if not all, of the rich capitals of the twelfth century are made of stucco, fixed upon the plain and rude early stone capitals of the eleventh. When I went there some years since, with M. Viollet-le-Duc, who was then in charge of some restorations in that

church, we saw one of the stucco capitals that had been broken, and inside of it the early stone capital. About the same time I saw the same thing at Jumièges, in Normandy, with M. Bouet, the excellent French artist who usually accompanied me in France, and he made a drawing of it, which I put into the fifth edition of the "Glossary of Architecture," in the description of the plates, which happened to be then in the press.

In the west front of Lincoln Cathedral the capitals of Bishop Alexander, of the twelfth century, are inserted in the early walls of Remigius. This I detected by the fine jointing of the masonry in the insertions, and the wide-jointed masonry of the early work. I had previously sent Mr. Jewitt to make me a drawing of one of the capitals of Remigius, of which there are a few remaining; but he drew me one of Alexander by mistake; and as he did not draw the jointing of the masonry (for no artist ever thinks of doing so), I did not at first discover the mistake, but saw it at once in a subsequent visit.

The well-known passage from Radulphus (Radolf or Ralph) Glaber, mentioning that "the world seemed to be putting on a new white robe," at the beginning of the eleventh century, which he witnessed, certainly indicates a considerable change at that time, a revival of building in stone, just as another incidental notice in William of Malmesbury, that the buildings of Roger, Bishop of Salisbury, in the beginning of the twelfth century, were so well built that it appeared as if each wall was made of a single stone, indicates that fine-jointed masonry was then first introduced into England as into Normandy. The Norman style is properly called by Viollet-le-Duc the "Anglo-Norman style." It was not introduced as a complete style by the Normans at the Conquest, but was gradually developed in all the provinces of the Anglo-Norman kingdom simultaneously: the variations between England and Normandy amount to no more than provincialisms. The Norman keep of the earliest character that we have either in England or in Normandy is the one built at Malling, in Kent, by Gundulph, in the early part of the reign of William the Conqueror. His invention exactly fitted the wants of the Normans settled in England, and therefore that type was rapidly followed and soon spread all over England and then to Ireland and the Continent. We find Norman keeps everywhere, even in Italy. I am fully convinced, both from my own experience and long observation, and from that of others whom I have known to be careful observers, that buildings of the tenth century are extremely rare, and that on the other hand the first half of the eleventh century was a great building era; and we have many buildings of that period remaining, although that fact has been usually overlooked, and those buildings are commonly supposed to be either much earlier or later. I believe that to be the case with the two rude small and early cruciform churches visited by the Institute in the summer of 1872—St. Mary's, Guildford, and St. Michael's, Southampton—both very much of the same character, and each enclosed in a much larger church of a later period. The construction is so rude, that it might be of any period when the art of building was in its infancy; but that is exactly what appears to have been the case when the revival of stone building began. It is not debased Roman art, but a rude imitation of it.

Professor Willis, in his admirable history of the Cathedral of Canterbury and Winchester, does not say that we have any building of the tenth century remaining in either. Archæology has to do with existing remains: "the things that have been" belong to history only. At Winchester the present church was built on a new site, near the old one, not on the same foundations. At York, Professor Willis ridiculed the idea of Browne's history on the very point that Browne supposed the existing building to be the original one. It is possible that there may be some small remains of it in the foundations of the crypt, but it is difficult to make out any, though it is on the old site. At Ripon and at Hexham the old crypts exist, built of fragments of Roman buildings; but their character is quite peculiar, not in the least like the Anglo-Saxon buildings. I have published engravings of them. The church at Bradford, as I have said, is an exceptional case; the fine-jointed masonry proves it not to be of the eleventh century, nor of the tenth; it is most probably of the eighth; although I do not remember one of that period like it anywhere. Still, as a window of the twelfth century seems to be inserted in the old wall, and this wall is certainly not of the tenth or eleventh, I conclude that it must be of

the eighth. Shallow sculpture was the fashion then, and the shallow arcade cut in the surface of the old wall may be of that period. I should be very glad if any learned friend would name any other building now existing of that period which corresponds with Bradford. I have spent several months in Aachen, and have drawings and photographs of the church or chapel there, and published a short account of Roman-Moutier and Lorsch, with engravings, in the "Archæologia." It is well known that very many of the legal documents of the latter half of the tenth century conclude with the words, "the end of the world being at hand;" and this general belief is likely to have had its influence on the buildings of that period, as it appears to me evident that it had. I do not know of three buildings of that period remaining in the west of Europe. We all know how the same buildings that are mentioned in grandiloquent terms by the Saxon writers are mentioned with contempt by the Normans a century after (more or less), and were often swept away as not worth preserving. At Soest I was once the means of saving a curious old church from destruction, which may possibly be called of that period; but from its construction I do not believe it to be so. The rules of archæological evidence are our safest guide to the date of a building. "The construction of the same period is always the same." In the only examples of that period that I know of, the construction is as bad as it well could be. This class of buildings is exactly what I mean by those of the first half of the eleventh century, or continuing rather later, perhaps from 1,000 to 1,080. The towers of this class in the lower tower of Lincoln we know to have been built after the time of the Norman Conquest. They are rather more advanced in construction than some of the others; they belong to the third generation of masons, after the revival of building in stone. The work of each generation of men may be traced by the construction and the architectural details of their buildings, from the the time of the kings of Rome, and of the re-building of the Temple of Solomon at Jerusalem, under King Ahaz, to our own days.

In the early period all the ornamentation was of wood and bronze; the wood has been burnt, and the bronze melted down, and we have only the rude massive stone walls of the original construction remaining; but these may be divided into three classes; as I have shown very distinctly in Rome, there is a change in each half century. Such changes are equally distinct in the Middle Ages in England, as is shown by the dates in my "Glossary of Architecture," the first work in which architectural details were ever dated by their historical types.

HYDRAULICS OF GREAT RIVERS.

From "Iron."

Three years ago M. J. J. Révy surveyed the estuary of La Plata and the two principal of the great rivers which form it. The work was executed at the instance of the Government of the Argentine Confederation, as a preliminary step to large engineering works then in contemplation. A work of this nature was certain to throw light on many hydraulic questions; and the methods of the survey, its results, and their application to problems partially settled, or till then wholly unsolved, have just been laid before the public in a manner rivalling in fulness but excelling in clearness the great streams surveyed. (The Parana, the Uruguay, and the La Plata Estuary. By J. Révy, Memb. Ins. C. E., Vienna, etc., etc. London: E. and F. N. Spon. 1874.)

The Parana, the principal tributary of the Plate, is a mighty river of great depth, and though traced for many hundred miles from its mouth, has never been found less than a mile in width. The Uruguay is over half a mile in its narrowest breadth; but both occasionally, especially in their lower courses, spread out much wider, with swamp and jungle-covered banks. On this account the use of levels, chains and theodolites was much restricted, and M. Révy, in the absence of even a single trained assistant, was forced to adopt new methods, as ingenious and effective as they were novel. Indeed, dealing with such vast masses of water and river-beds on such an enormous scale—the La Plata being at least 20 miles across at its narrowest width

—the old-established methods would have been of little use. A small steamer, the Aguila, with the necessary adjuncts, was placed at the disposal of M. Révy, and about the middle of January he sailed to survey the Parana. The river was then beginning to rise to the level which it retains, with little variation, during March, April and May. A base line was measured on the bank, and the gauge fixed. It showed a steady rise at about the rate of an inch in the 24 hours. M. Révy advises that the gauge should be put down wherever possible, even where there is no intention of taking a section. The first cross section was taken about 12 miles below San Rosario. The depth of water was not gauged in the usual way by means of marks on the sounding line, that having been found inaccurate, but the cord was drawn on deck, and measured with a tape. The steamer was managed so that it drifted with the same velocity as the current, and then the lead was lowered, and the soundings taken as if on a mill-pond, the exact line of section being indicated by the flag on the extreme end of the base line, and two on the line of section covering each other. From check operations these soundings were found accurate to the inch of depth. The determination of the current was effected by means of water meters, an improvement on the ship's log which, M. Révy says, gives superficial currents with great accuracy. With the deeper currents, however, the instrument failed him; but he was equal to the occasion, and, with a bar of iron replacing the wooden rod used for surface currents, and a simple but ingenious method of mooring it at the requisite depths, he had an instrument which never once failed him at any depth. Not only so, but he was enabled to integrate all the currents from surface to bottom in a vertical plane, and so find the absolute mean of all the different currents in a vertical line at the point of section. This improved instrument M. Révy names the "Current Integrator;" a still further improved form of it is described in the appendix. For the complete details of M. Révy's method, which are much too full for enumeration here, such of our readers as may be interested in the subject are referred to his book.

Indeed, the facts there recorded are so new and so numerous, and depend for full elucidation so much on the diagrams and figures, that we shall probably best accomplish our task by simply recapitulating a few of the leading results of this important survey. And first, as to the estuary La Plata. The River Plate is about 125 miles long, varying in breadth from 23 to 63 miles, and ranging at low water from 3 to 6 fathoms in depth. The original length of the estuary was about 325 miles, but 200 of these have been filled by the deposits brought down by the Parana, which, *pace* Dr. Cumming, will doubtless in time wholly fill up the La Plata; for why may not rivers like men be "immortal till their work is done"?

Of the Parana, M. Révy says it is practically unknown in Europe out of the hydrographic department of the British Admiralty. Ships are guided through the intricacies of its lower channel by native pilots, who never look on a chart, but, brought up on it from boyhood, know every tree on its banks, and every change of its shifting bars, and rarely meet with mishaps. The scenery in the lower reaches of the delta is described as very fine, the river gliding along without a ripple in the midst of stillness the most profound, and the banks gay and glowing with bright flowers amid a setting of dark green foliage. For some reason the margin of the river is scant or void of animal life, even birds, abundant a little inland, are scarce along its margin. About 270 miles up the Parana its left bank is bounded by a "bluff" about 200 ft. above the level of its waters, supplying an excellent section of the latest geological formation of the country.

The plain traversed by the Parana, bounded on the west and east by the Andes and the Atlantic, and south and north by the Straits of Magellan and the mountains of Brazil, is the largest tertiary basin in existence. The lower strata are sandstones of marine origin; regarding that of the upper, which is the land of the present day, geologists are not agreed. It is probably an estuary formation, and filled by the rivers which drained the land then above the sea level, and deposited in their embouchures the bodies of the animals that then flourished in its forests. These remains include those of the mastodon, cerodon, milodas, several stags, evidently contemporaneous with the great mammals the remains of which occur in similar superficial formations in Europe, immediately prior to the glacial epoch.

The upper portion of the Parana is

wholly unexplored, and about 700 miles above Corrientes, an immense fall, called "Guaira," puts an end to navigation. The river a little above the fall has still a width of two miles and a-half, and contains more water than all the rivers of Europe united; but this immense width is at once reduced to a narrow channel of about seventy yards, in which its waters break, in the words of an eye-witness, "with indescribable fury, not in a vertical line, but upon a plane inclined about 50 deg., forming a clear drop of about 20 yards measured vertically; the clouds produced by the concussion of the water against the walls of its granite channel and on the rocks which project in the middle of the current, forming columns of steam, which may be seen for several leagues, and in which numerous rainbows are visible. A continuous rain, produced by condensation, falls in the neighborhood; the noise of the cascade is heard 6 leagues distant, and close to it one believes the earth is trembling" And Domingo Platiño, sent, in 1863, by the Dictator of Paraguay, Carlos Lopez, to explore the Parana, and who, after much privation, reached as far as the Great Fall, says: "The thunder-like noise of the Fall could be heard at a distance of ten leagues, and within one league the noise was so great that it was difficult to hear one another; at the Fall itself it was impossible to distinguish any voice, all being drowned in the thunder of the terrific concussion of contending waves. It was not a vertical drop which caused the thundering noise, but the concussion of immense waves which broke upon vertical granite walls, narrowing the ordinary width of the Parana to about 70 metres; the difference between the upper and lower level may be about 20 metres." He adds, "it is reported that the settlements close to the Fall of Guaira had to be abandoned on account of the noise, which made the population deaf." The bulk of the volume of the Parana is derived from a great number of rivers and innumerable torrents rushing from the tropical mountain ranges of Brazil, its drainage area extending over many hundred thousand square miles, and it is probably the greatest river in the world.

The Uruguay was surveyed by the methods employed on its sister river. M. Révy characterizes it as at times a mighty stream, rivalling the Parana; at others, sinking into comparative insignificance. "The Parana is," he says, "a great river at all times, conveying an immense volume to the Atlantic, at its lowest condition never falling to 50 per cent. of its ordinary flood volume. The Uruguay is subject to frequent and remarkable fluctuations; during great floods it rivals the Parana, and one month later sinks to a small percentage of its former greatness. The Parana is the type of a truly great river; the Uruguay represents a mighty torrent of extraordinary dimensions."

The conclusions which M. Révy draws from his investigations are clear, philosophical, and highly important, while they have a direct and most useful bearing on our own noble river and its altered conditions depending on the great work which now confines its waters between Westminster and Blackfriars. The results of his survey, he contends, place the question beyond doubt that the accepted principles upon which hydraulic engineers based their arguments when the movement of water in open or confined channels had been under consideration, were at variance with those of nature. His observations, he maintains, disclosed and established the dependence between depths and currents; that at a given inclination surface currents are governed by depths alone, and are proportional to the latter. "The greatest current is at the surface, the smallest at the bottom; as the depth, however, increases, or the surface current becomes greater, so the difference between surface and bottom currents will be smaller and smaller, approaching equality, until in great depths and in strong surface currents they are substantially alike."

Finally, he observes: "The science of river engineering had been comparatively neglected. In no other branch had graver or more expensive blunders been committed. No doubt it was in a great measure guesswork—matter of opinion—reasoning upon the solid basis of observation having been at a discount. Rivers inundate vast tracts of land, and continue to do so, not because they have too much water, or that their depth is not great enough, but because we are too shallow to offer the proper remedy, which, in nine cases out of ten, it would be in our power to give, and under our control to accomplish. Channels of estuaries and harbors silt up, and then navigation becomes more and more difficult, not because the action

of the sea is different to-day from what it was a century ago, but because we are, in the first place, more alive to alterations; and, in the next, because in many instances we had already aggravated the situation by desultory attempts at improvement.

There is hardly a more intricate problem than the consideration of currents, and their ultimate effect on the channels of an estuary; yet, with but few exceptions, 'improvements' are made without an attempt to trace the history of an estuary, much less the causes at operation; and we generously leave it to the next generation to reflect over and learn by our present mistakes."

SCIENTIFIC AND INDUSTRIAL EDUCATION IN THE UNITED STATES.*

From the "Albany Evening Journal."

A little more than two hundred years ago, —in England of the Round Head and Cavaliers—a voice was raised to propose that young men be instructed in branches bearing on the various national industries.

He who proposed this was a man of great genius—one of the true priests and prophets of his time. He foresaw and foretold many great modern inventions, and among them the steam engine. His brain helped to think out its principles — his hands helped to shape its groundwork. With pen and tongue he sought to promote the "new education"—but he had fallen on evil times. With Straffords and Lauds on one side and Hampdens and Cromwells on the other, there was but poor hearing for the industrial ideas of the Marquis of Worcester. Persecuted, maligned and a bankrupt, he died, and to all appearance his idea died with him. For two centuries afterward Oxford and Cambridge solemnly ground out the old scholastic product in the old scholastic way.

About 50 years ago a body of the best scholars and thinkers in England made another attempt. Their endeavor was to found an institution giving an education fitted to the needs of their land and time. They established the University of London. Never had a plan more brilliant advocates. Brougham, Sidney Smith and Macaulay spoke and wrote for it;—but their success was small. The institution was unsectarian, therefore the Church declared against it as "godless"—it gave instruction in modern learning as well as in ancient learning, and therefore the great body of solemn scholars declared it unsound. Some of its ideas and methods were new, and therefore a multitude of leaders of society declared it unsafe. The institution was kept down, and from that day to this has never taken the high place to which its plan and work entitled it.

About 30 years since, the greatest man who has ever stood in an American College Presidency made an effort in the same direction. Francis Wayland knew what there was of good in the old scholarship and was loyal to it, but he saw that new times made new demands, and he planned out and endeavored to work out a system of education which should meet these demands. All to no purpose. It was the old, old story—another great man, with his great idea, as Carlyle phrases it, "trampled under the hoofs of jackasses," or as Wayland himself phrased it more mildly, "nibbled to death by ducks."

Various minor attempts were made—some of them, like Eaton's noble effort at Troy, very fruitful—but no great general plan, no large institution was created worthy of the great interest involved.

About five years later, Mr. Lawrence, of Massachusetts, a thoughtful manufacturer, made another attempt. He saw the necessity of education bearing on the great industries of the country, and made to Harvard College what in those days was called a princely gift. Thus was founded the "Lawrence Scientific School" at Cambridge, and thus did industrial studies get their first foothold in a great university.

About five years later still, Mr. Sheffield, of Connecticut, also a thoughtful business man, recognized this great necessity. By a generous donation he founded the "Sheffield Scientific School" at Yale College, and thus

* Extract from an address delivered before the State Agricultural Society at Albany, by Andrew D. White, President of Cornell University.

these studies got foothold at a second great university.

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(Speaking of practical instruction in our technical schools, President White continues.)

Indeed, I know of no more pressing national need in this country. Our land has more mechanical ingenuity in it than any other; but did you ever think of its wretched misdirection and waste for want of industrial education? If not, stroll through the national Patent Office. Look at a few facts. In one of our most important cities are engines for supplying that city with water—erected at vast expense. The whole amount was wasted. There is ingenuity in that vast machine, there is skill in it; but for want of education regarding certain principles involved, the whole thing is failure and waste.

Take another case. A few years since, with a small party of our fellow-citizens, I visited the West Indies in a national ship. She was a noble vessel and her engines had cost, it is said, nearly $800,000. The engines showed ingenuity; but they were so deficient in proper elements of construction that our voyage was prolonged until we were all given up as lost and had the honor to have our obituaries in the leading newspapers. The first voyage of those engines was the last. They were sold for old iron, and the sum lost on them alone was sufficient to endow the finest institution for mechanical engineering in the world. I might multiply examples of this sort; but this is enough to show what need exists for more careful training in the direction, and I pass to a kindred department.

CIVIL ENGINEERING.

Another great department, bearing on a multitude of industries, directly and indirectly, is civil engineering. Take one among the fields of its activity. We have in the United States about 70,000 miles of railway, and every year thousands of miles are added. I do not at all exaggerate when I say that millions on millions of dollars are lost every year by the employment of half-educated engineers. Proofs of this meet you on every side. Lines in wrong positions, bad grades and curves, tunnels cut and bridges built which might be avoided. All of us know the story.

But this is not all. Hardly a community which has not some story to tell of great losses entailed by bad engineering in other directions. Here it is the traffic of a great city street interrupted for a year because no engineer can be found able to make the calculations for a "skew-arch" bridge, a thing which any graduate of a well-equipped department of engineering can do; there it is a city subjected to enormous loss by the failure of its water-supply system, because the engineer employed made no calculation for the friction of water in the pipes; in another instance it is a whole district sickened by miasma, because a half-taught engineer was intrusted with its drainage. We must prepare men for better work, and for every dollar thus laid out we shall create or save thousands. Nay, we shall save lives as well as money. Mr. Baldwin Latham, in his recent book on Sanitary Engineering, and Dr. Beale, in his work on Disease Germs, show by statistics that a proper application of engineering to sewerage would save 100,000 lives yearly in Great Britain alone, and the same truth holds in this country.

ARCHITECTURE.

Wealth and public spirit—individual and municipal—are now erecting myriads of noble buildings in all parts of our country. The number of uneducated architects is very great—the number of thoroughly prepared architects is very small. Have you ever considered the waste attendant upon this? Every month you hear of some architectural failure that costs life and treasure. To-day it is a church floor which gives way and a multitude of children are taken from the ruins mangled and dead;—to morrow it is a whole city quarter swept away by fire, because some half-taught architects knew no other way of producing architectural effect than by piling up combustible ornaments on inaccessible roofs.

Nor is that all. Our people are laying out millions on millions in buildings which within 30 years—in the advance of taste and knowledge—will be eyesores and must come down. A building erected by a true architect will grow more beautiful for hundreds of years. A building erected by a sham architect will be an incubus in a quarter of a century. Men are beginning to see this, and we are endeavoring to prepare men thoroughly to know the best materials—to calculate their strength in construction and to combine material and construction according to everlasting laws,

and not according to some pretty present fashion; and this is the purpose of our School of Architecture.

THE ARTS OF DESIGN.

The average visitor to an institution like that established in this State will often say something like this: "I can understand the value of your libraries—collections in Natural History, apparatus, models, shops and lecture rooms, but what use of your great draughting rooms?"

If you answer that drawing is taught in one for Civil Engineers; in another for Mechanical Engineers; in another for Architects; in another free hand drawing for all these together, he will say, "Why teach free hand drawing at all? That is rather artistic than industrial."

Is it? Look at a few recent facts. A few years since, the State of Massachusetts passed a law requiring free hand drawing to be provided for in the public school system throughout the State. The city of Boston did the same. State and city combined to call from the great English school for Industrial Art at South Kensington, Mr. Walter Smith at a salary of $5,000 to direct the schools of that city and State.

Mr. Smith has worked on and the result is that already this instruction has been admirably developed. Now, why has this been done? Has the State of Massachusetts, which we have always known as so thoughtful in its legislation and education, really fallen into mere dilettantism? Not at all. Look at a few more figures from the census.

In 1870 the product of Massachusetts in printed cottons was over $17,000,000, and her product of other goods into which the arts of design enter as a matter of first importance was doubtless even more. Massachusetts is thoughtful as ever. She sees that other States are overtaking her in manufactures so far as quantity and quality of material are concerned, but she determines to distance them by spreading throughout her borders a knowledge of the principles of beauty in design and skill in them. And she never did a wiser thing. It will tell on a multitude of industries. Why do we import such vast quantities of English, German and Danish glassware and pottery?—because they are better in material than ours? No; but because they have a beauty in design which leads the most illiterate to choose them. Why do we import such quantities of silks and carpets and chintzes and wall papers from France? The Cheneys make silks as good in quality on this side of the ocean as the Compagnie Lyonnaise make on the other; the Bigelows make carpets just as good in material here, as the D'Aubusson factory makes there, and yet when our wives and daughters see these foreign fabrics, they immediately prefer them. Why? Simply because there generally is in the foreign product a skill, a beauty, a taste in design that appeals to that sense of beauty which God has implanted in the rudest of our race.

Other nations in this warfare of industry see this. England is devoting millions to art education, in order to keep up her manufactures, and it has established in the Privy Council a science and art section to direct this expenditure wisely; Germany is doing even more; France has been doing it for generations, and it has given her the supremacy thus far in a multitude of branches of manufacture.

If you wish to see how these nations have done and are doing this, look at Mr. Stetson's admirable little book on "Technical Education." You will there see that Prussia alone gives industrial education in various branches to over 11,000 men.

Already the value of this is known to individuals among us. Mr. Stebbins tells us that one silver-ware establishment in the city of New York pays a graduate of one of these foreign schools for making designs and patterns, as high a salary as our Empire State gives its Governor.

MINING ENGINEERING.

Few among us dream of the monstrous waste now entailed upon this country by imperfect instruction in mining engineering and metallurgy. Take first the losses by fraud. A few years since our people were asked to invest in a Nevada mine of great richness. Half educated mining geologists had certified to its value. But certain capitalists sent a young man carefully educated in the Scientific School to examine and report. The young man on arriving found that the mine looked well enough, but on applying more scientific tests he found that an old worthless mine had been taken — that rich sulphurets had been brought and carefully placed in it at a cost of probably $100,000. His report exploded the fraud, and nearly $1,000,000 was saved —more than five times the sum that this

scientific school received from the Government of the United States. This same gentleman also exploded a great diamond mine fraud of the same sort.

Take another case. Not long since a party of gentlemen determined to invest several hundred thousand dollars in working certain iron mines in this State. Just before their arrangements were finally made, and much against the will of many of the proposed stockholders, a young graduate of one of our scientific schools which received the national endowment, was sent to make an examination. He found that the veins contained titanium, and that the entire investment, should it be made, would be lost. His fee was $250; he prevented a loss of over $400,000.

You see now why Pennsylvania and Missouri, and California and Massachusetts, are aroused as to this matter also, but you will perhaps say that New York is little interested here. Look again at the census, and you will see how wretchedly you are mistaken. The value of the mining product of New York, in 1870, was more than half that of the entire gold product of California. Here, too, we must follow up the good work begun by our Chandlers and Raymonds.

CHEMISTRY APPLIED TO MANUFACTURES.

More and more the chemical laboratory is becoming a great central point in industrial education. Run over but two or three points out of many. A chemical discovery in coloring matter has given us a substitute for madder, and restored the great area given to cultivation of that material to the increase of material for human sustenance. An apparently trivial application of another chemical principle has enabled Onondaga to purify its product so that it now competes with the world in the purity of its salt for the dairy. Another application has enabled another part of the State to make quantities of steel formerly undreamed of. And all this is but the beginning of the applications of chemistry to increase the well-being of the State and Nation.

GENERAL INSTRUCTION.

And now a few words regarding the general education which goes with these various branches of industrial and scientific education. The old way in the more venerable colleges and universities was to force all students through one single classical course—the same for all. This system the "new education" discards. General courses in literature, science and arts, are presented as well as special courses having reference to the great industries, and the student with the advice of friends and instructors takes that which best suits the bent of his mind. We believe that the results are already better than those of the old system. Certainly they could not be worse. The famous Blue Book of the Parliamentary Commission on advanced education in England shows that under the old system there 70 per cent. of the students in their great schools and universities take no real hold upon classical studies. Few will claim that our system of classical instruction is better than that in England. We make no opposition to classical instruction. We agree that for those who take earnest hold of it, it is one of the noblest means of discipline and culture, but it is no less evident that for those who do not take hold of it—who merely "drone" over it—it is one of the worst.

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SCIENCE, INDUSTRY AND RELIGION.

And finally it is objected to the "New Education" that it is "godless." There is nothing new in this charge. It has been made against every great step in the progress of science or education. And yet it has certainly been found that although ideas of religion are changed from age to age, the change has tended constantly to make these religious ideas purer and nobler. The majority of the Fathers of the Church held the new idea of the rotundity of the earth incompatible with salvation. Martin Luther thought Copernicus a blasphemer for his new idea that the earth revolves about the sun, and not the sun about the earth. Dean Cockburn declared the new science of Geology a study invented by the devil, and unlawful for Christians. When John Reuchlin and his compeers urged the substitution of studies in the Classics for studies in the Mediæval scholastic philosophy, their books were burned and they themselves narrowly escaped the same fate.

No, my friends, every study which tends to improve the industry of mankind makes men nobler and better. Every study which gives man to know more of the history of his race, gives him to see more and more clearly the finger of Providence in history; every study which brings his mind into contact with the thoughts of inspired men as exhibited in our literatures, builds up

his manliness and his godliness, and every study which brings him into close contact with nature in any of its fields not less surely lifts him "through nature up to nature's God."

I have thus sketched very meagrely the growth thus far of the "New Education." Its roots are firm, for they take fast hold upon the strongest material necessities of our land; its trunk is thrifty, for it is fed by the most vitalizing currents of thought which sweep through our time,—nay, the very blasts of opposition to this growth have but strengthened it. The winter of discontent through which it has passed has but toughened it; and in Agriculture and every branch of industry; in every science and art which ministers to either; in all the development of human thought which is to make men better and braver, it is to bear a rich fruitage for the State, for the Nation, and for Mankind.

PORTLAND CEMENT AND HOW TO USE IT.

From "The Architect."

Bad Portland cement is worse than useless, and is often the cause of serious failures, but it is just as unreasonable to abuse a good material, or in practice to treat it as if no reliance should be placed on it, as it would be to buy sand for sugar, and then to give up the use of sugar because the mixture bought was wanting in sweetening properties. The remedy is to see that you get the article you pay for; in order to do which, the first thing is to have a clear idea of the qualities which good Portland cement, suitable for all ordinary purposes, should possess. These may be described as follows:

CHARACTERISTICS OF GOOD PORTLAND CEMENT.

It should, when passed through a copper wire sieve of 2,500 meshes per sq. in., not leave more than 20 per cent. of grit behind. The cement sifted should not be less than 25 lbs., taken from different bags, or from different parts of the heap if stored in bulk. After a little experience a well-ground cement may readily be recognized by the absence of grit when rubbed between the fingers.

When made up without sand or excess of water, and filled up level with the top of a glass or similar vessel, it should set hard without cracking the vessel, rising or sinking or getting loose in it, or showing any signs of cracks in the cement itself.

When made up without sand, with as little water as possible, and filled into moulds, it should, after seven consecutive days in water, give an ultimate strength, under a tensile stress slowly applied, of 250 lbs. per sq. in. of fractured section, the immersion in water to commence as soon as the cement blocks will bear removing from the moulds, which should not exceed twenty-four hours after the moulds have been filled.

When time will not admit of this test being applied, a very fair idea of the strength of the cement can be arrived at from its weight, which should not be less than 108 lbs. per imperial striked bushel, filled up as lightly as possible, by pouring the cement down an inclined board, or through a wooden hopper, about 1 ft. sq. at top, 1 in. sq. at bottom, and 1 ft. deep. The hopper should be suspended with the point of discharge 6 in. above the top of the bushel measure, which should stand on a firm base and not on any vibrating floor, and should not be touched until the cement in it has been finally struck level with the top with a straight-edge. The cement weighed should be taken from different bags, or from different parts of the heap if stored in bulk.

When made up into cakes about ½ in. thick, without any sand or excess of water, the cement should set hard within 24 hours, either in or out of water, without showing any signs of cracks.

The color of good Portland cement is a bluish-grey; if dark and earthy, or of too light a color, it is not to be trusted. When made up without sand and set hard, it should show the same bluish-grey color without any brown specks or stains.

A high degree of fineness is necessary to the complete and simultaneous setting of all the particles throughout the mass. When insufficiently ground, the fine particles set first, then the coarser grit, and lastly the little hard lumps; and it is this process going on, after the surrounding particles have already set hard, which often

shows itself all over the surface by the "blowing" or bursting out of numberless pustules, or the cracking of the entire body of the cement.

Some foreign cements allow of 85 per cent. passing through a No. 60 gauge, or 3,600 meshes per superficial inch; but cements of such extreme fineness are underburnt, and therefore weigh light, and are deficient in strength, though often rapid in setting. The wear and tear to the machinery in grinding well burnt cements to such extreme fineness would render them too costly to be marketable.

The test for expansion or contraction in setting is very simple, and one which should on no account be omitted, for these are about the most serious defects to which Portland cements are liable, though for the most part no steps are taken to guard against them.

Expansion in setting is due to the presence of free lime in the cement—owing either to more lime having been used in its manufacture than can chemically combine with the clay—to imperfect mixing of the lime with the clay, or to the burning not having been carried to a sufficient extent to enable the lime and clay to combine together.

Contraction in setting, which is not nearly so often met with, is due to an excess of clay, and, as there is no remedy for this evil, the cement must be rejected.

The tendency to expand in setting is a very common fault in fresh ground cements, especially those of the heaviest and strongest descriptions, owing to the large proportion of lime used in their manufacture, which, if in excess, as already explained—or even locally in excess, owing to imperfect mixing—is present in the cement in the form of free lime, which heats and expands considerably in the process of slaking. However, if the cement is otherwise good, this evil can be remedied by spreading it out on a dry floor, under cover, and turning it over occasionally, to allow of its air slaking or "cooling." Good cements are found to gain both in weight, bulk, and strength by being exposed to dry air for a few weeks, though the limit of such improvement has not yet been definitely ascertained. On this subject, Mr. Bernays, C. E., Superintending Engineer, Chatham Dockyard Extension Works—whose experience in the use of Portland cement is very extensive—in a lecture given at the School of Military Engineering, Chatham, says:—

"When delivered on the works for use, Portland cement should always be shot from the bags on to a wooden floor—to a depth not exceeding 4 ft.—and be permitted to remain at least three weeks before it is allowed to be used for any purpose. While so kept, fresh Portland cement increases considerably in bulk—probably 10 per cent.—without any diminution of its strength; so that it should be to the advantage of a contractor to store his cement before using it, even if he were not required to do so by the engineer. I can hardly impress too strongly upon you the importance of avoiding the use of fresh cement for any purpose whatever."

Many a good strong cement which, when first delivered, would heat in mixing and expand in setting, would, after exposure to the air for a time, stand the test for expansion perfectly; but after such exposure, the other tests should be carefully applied, in order to insure its not having deteriorated in strength and rapidity of setting. A further advantage gained by spreading the cement out on a floor, where large quantities are being used, is that it tends to mix up the contents of the different bags or casks, and so to produce a greater uniformity of quality throughout.

The cement for the test blocks must be carefully made up without excess of water, and the moulds well and soundly filled in, or its full strength will not be developed. If, in the absence of a proper testing machine, the strength test is applied by suspending weights in a scale, or otherwise, slung from the lower end of the cement blocks, the gradual increase of the stress should—after about 150 lbs. per sq. in. has been applied—be insured by pouring water or shot into a vessel suspended from the block, or by placing a chain, link by link, in the scale or in a pail suspended from the specimen. It is not wise to aim at obtaining very heavy cements capable of attaining extraordinary strength, and therefore it is that the strength test, as given, is put at 250 lbs. per sq. in. of fractured action, instead of at 300 or 350 lbs., as is very commonly insisted on in modern specifications. Great weight and strength mean high burning and slow setting, the former resulting, as already explained, in coarse grinding, with all the attendant risks of blowing and crack-

ing, and the latter in deferred strength; but it should be remembered that in practice the cement will, as a rule, be called upon within a few weeks, or months at the most, to do as much work as it will ever have to do, and therefore, that if strong enough then, it will be strong enough always; consequently, that any extra strength acquired a year or two later will be of no practical utility.

In judging of the strength of cements from their weights, the fineness test must never be omitted, since weight may in a great measure be due to coarseness. If great strength is required it will always be safer to use a moderately heavy cement with less sand or other material mixed with it, than run the risks attendant upon the use of the heavier cements, with a larger proportion of sand.

For common purposes, such as pointing, when cement of a very high quality is not necessary, and no tests are ordinarily made, it is always advisable to mix one or two parts of sand with it, and not to allow it to be used neat, in order to guard against its shrinking in setting, which, in the case of pointing, would make it loose in the joints, and lead to the wet and frost getting in, and to its soon requiring renewal.

Very rapid setting and great strength are not met with in the same cement; but in many cases the quicker setting and lighter cements are most useful. It is believed that before long light Portland cements will be manufactured, capable of competing with the Roman cements in quickness of setting, and surpassing them in quality.

The following table contains the result of a series of experiments made by Mr. J. Grant, C. E., whilst engaged on the Metropolitan Drainage Works, with Portland cement, weighing 123 lbs. per bushel:—

Average Breaking Test of Ten Specimens.

Age.	Neat Cement.	1 Cement, 1 Sand.
	lbs.	lbs.
7 days	817.1	353.2
1 month	935 8	452.5
3 "	1055 9	547.5
6 "	1176.6	640.3
9 "	1219 5	692.4
12 "	1229 7	716.6
2 years	1324 9	790.3
3 "	1314.4	784.7
4 "	1312.6	818.1
5 "	1306 8	821.0
6 "	1308.0	819.5
7 "	1327.3	803.6

The whole of the specimens were kept in water from the time of their being made up to the time of testing, and the breaking weight applies to a sectional area of 1½ in. sq., or 2.25 in. super. It appears from these experiments that neat cement of 123 lbs. per bushel took two years to attain its full strength, whilst the admixture of sand, in addition to weakening the specimens, also delayed their attaining their maximum powers of resistance.

A dull earthy color denotes an excess of clay; whilst too light a color is the result of either under-burning or an excess of lime, or of both these faults combined.

Since Portland, unlike Roman cement, improves within certain limits by exposure to the air, it need not be packed in air-tight casks (except for exportation), but, so long as it is kept dry, may be kept in ordinary casks or bags as may be most convenient. The casks in which it is packed generally contain four cwt., and the bags two cwt.

Salt water does no injury to the strength of the cement, but must be avoided where efflorescence or damp on the surface would be objectionable.

Both cement, mortar, and concrete should be made with as little water as will suffice to make the whole cling together. When too much is used, the finer particles of the cement get separated from the rest and float away, or on the surface, in the form of a slime. In mixing concrete, if the ballast is porous and dry, more water will be required than if damp or non-absorbent.

Experience has shown that porous materials, by allowing the cement to enter the pores and so retain a firm hold on them, are the best for mixing with cement; thus, well-burnt broken bricks, clay ballast, furnace slag or breeze, will form a stronger concrete than if made with the harder but smoother and less porous stones in gravel or shingle; but it must be borne in mind that in such cases a slightly larger proportion of cement is advisable to compensate for what is absorbed by the pores of the material.

No importance need be attached to the shape of the particles of sand or other materials used—such as whether angular or water-worn—though a certain roughness of surface gives a better hold to the cement than if too smooth. The presence of dirt,

such as loam, clay, and vegetable matter, liable to decay, has a prejudicial effect upon cement, and sensibly weakens either mortar or concrete.

The gravel, broken stone, or other material used in making concrete, should have sufficient small stuff and sand mixed with it to fill up the interstices between the larger pieces. When this is not already the case, the amount of small stuff and sand which ought to be added may be ascertained by filling up any suitable measure, of uniform section from top to bottom, with the gravel, etc., striking it level with the top, and then adding as much water as the measure will contain. The water may then be run off through a hole in the bottom of the measure, the gravel, etc., removed from it, and the water replaced in it; the amount of water, expressed in terms of the internal height of the measure, will be the proportion of small stuff which should be added to the ballast.

As cement is not used, on account of the cost, unless special strength is required, the proportions in general use are 1 cement to either 1 or 2 sand; below this the advantage gained by its use diminishes rapidly. In general terms, neat cement is $\frac{1}{3}$ stronger than if mixed with 1 sand, and twice as strong as when mixed with 2 sand.

For concrete, 1 cement to 10 or even 12 gravel, or other material, is sufficient for masses in foundations, dock walls, etc.; 1 to 8 or 6, for ordinary walls, according to their thickness; and 1 to 4 for floors, and other places where great transverse strength is necessary.

The best method of mixing concrete in large quantities is, taking a measure of convenient capacity for one mixing, to half fill the measure with the broken ballast, or other material, and then add the cement; finally filling up the measure with the ballast. The measure should then be lifted off, when the whole will fall into a heap, the cement partially mixing with the ballast in so doing, and not being so liable to get wasted by being blown about by the wind, as when emptied over the top of the ballast heap. The whole should be turned over twice dry, and then shovelled to a third heap, sufficient water only being added in so doing—by sprinkling from the rose of a watering pot—to make the ingredients cling together in a pasty mass. The floor on which it is mixed should be hard and clean.

The concrete may either be wheeled off and deposited in position, or, if more convenient, may be thrown down; but in both cases, more especially in the former, it is advisable to beat it down lightly with wooden beaters until the moisture comes to the surface.

On no account should it be sent down a shoot, or the finer and coarser ingredients will get separated in the descent, the former clinging more to the sides of the shoot, whilst the latter will reach the bottom first, and get shot out into a heap by themselves.

When cement work has once been laid, it must not be touched until quite hard, for its strength will be materially affected if the particles are disturbed after the process of setting has commenced.

All absorbent surfaces or materials, with which cement is to come in contact, should be well wetted, or they will rob the cement of the moisture necessary to enable it to set hard; but the water should not be oosing out of them, or the cement, being unable to enter their pores, will fail to adhere properly to them. For this reason broken brick ballast, etc., if quite dry, will require more water in concrete making, than if already damp, and old dry walls will require more wetting than new or external damp walls.

Cement work must be kept damp until set quite hard, or it will become rotten from the evaporation of the water of mixing, which is essential to the proper setting of the cement; hence the most suitable time for executing cement work is in damp weather. When the work has to be done in dry weather, special care is necessary to keep it damp, and to protect it from the sun's rays. Flat surfaces, such as floors, paving, etc., should, if practicable, be kept flooded with water or covered with a layer of sawdust or sand 3 or 4 in. thick, which should be kept quite damp for at least seven days, or until the cement has become quite hard. In surfaces exposed to traffic, this is most important, as the cement, if at all perished, will soon wear away.

Cement mixed with sand and other materials is porous, admitting both moisture and air; iron, therefore, imbedded in cement work, is liable to rust, and the expansive force accompanying this process, will split up cement, stone, or any similar unyielding material.

MACHINERY AS APPLIED TO THE MANUFACTURE OF WATCHES.

By T. PERKINS.

From "The Engineer."

That our American cousins have gone far ahead of us in the application of labor-saving machinery is a truism which has become almost stale by repetition, and is capable of proof by reference to their very complete "Patent Office Reports," or to the pages of their scientific and technical journals. Scarcely can we find a department of trade in which some automatic machine does not supply the place of dear skilled labor. But in no branch of manufacture has automatic machinery proved such a thorough success as in the production of watches. In the manufacture of small arms, the application of machinery to the making of interchangeable locks and stocks revolutionized the trade, and to this manufacture are the Americans indebted for a system which has supplied them with a home-made watch; for a system which is ultimately to become the leading one alike in England, France, and Switzerland. It is useless for English watch manufacturers to say "the thing can not be done, the machine-made watch can not beat the hand-made English lever in the home market." To their own cost, the record of the past proves the fallacy of such argument. Twenty years ago, America was supplied with her better class of lever watches almost wholly by Coventry and Liverpool, the demand for a common article being met by a large importation of movements of Swiss and French make. To-day, these latter countries supply, still, the enormous demand of the States for cheap work, but more than 90 per cent. of the good lever watches are now of American make. The machine-made watch has supplanted not only the product of the skilled French operative, but that of his more highly skilled English brother.

The reasons which have led to this result are diverse. National pride *may* have had something to do with this, but the protective tariff, so often put forward by the watch trade as the leading reason, has had positively nothing to do with the defeat of the hand-workers, who gave up the contest ingloriously. The truth is that the American watch companies have never yet known anything of trade competition, have never yet been able to keep pace with the demand for their products, and the main portion of their success must be attributed to their machinery—to the fact which is becoming more and more evident daily, that machines planned by brains at once scientific and practical must beat the simply practical rule-of-thumb workman, and that arms and muscles of iron will outwork and outlast mere flesh and bone. At the present moment, the watchmakers of England are unable to supply the home demand for their products, and it may therefore be *apropos* to draw attention, for a few minutes, to the machine-system as applied in the United States. As is generally known, the English system divides the manufacture into a vast number of branches, in each of which the work is performed by hand, or by the use of very simple lathes, driven by manual or foot power. In only three instances in England, are we aware of the employment of steam power in the production of watches, and in one instance only, is duplicating machinery used, and then only in the production of the plates or the rough movements. The American system subdivides the manufacture into a much larger number of details, and apportions a machine to the perfection of almost each operation, leaving not more than 10 per cent. of work to the skilled workmen.

It will be, perhaps, best for us to indicate, in a few of the departments, the advantages and saving effected by the machinery employed. First, in the manufacture of the movement. In the preparation of the plate a principle is laid down in the first punching performed on the circular sheet of brass. We want our movements interchangeable. To do this we must make our holes of all kinds, in exactly the same position in each watch; we must always, in determining a position in the watch, have some relative position from which to revolve it. The three dial feet holes immediately suggested themselves as affording a means to the desired end, and the punch was therefore brought into requisition to place these holes at certain angular distances from each other in all plates of any series. Here, then, we find machinery supplying the means of at once determining the position of each pivot hole in the watch, it being necessary only to prepare a chuck, on the face of which are three studs

so placed that when the plate is laid on its face with the studs in the dial feet holes, the drill finding the centre of revolution shall correctly make the hole required. And it is very easy at once to see how this principle may be applied to the determination of every hole in the watch. No templet plates and drill guides are here needed, with their uncertainty and subsequent filing and fitting; no running of each depth, with marking and cross-marking, dotting and hand-drilling, topping or stretching to make or correct depths. But the position once laid down is certain in each plate until the chuck is worn out.

The American spring-chuck lathe is too well known to need description, and yet it forms a ready means of securing a reproduction of any required height or thickness of turning. In the ordinary form the merely casual observer will see that if the rear bolt which draws the chuck down to the bevel be tightened a little more or less, the piece held will be thrown a little further from or nearer to any fixed tool or cutter, and therefore no advantage could be gained over the old cut-and try system. This is overcome, however, by making the chuck face a fixed position, and by closing it on the piece to be held by advancing the spindle bevel from the rear. It will be seen at once what is gained. The piece to be shaped and the operating tool are always in relative positions that can be relied on, but little judgment is required of the workman, who has only to keep the tool in order, to insert the work in the lathe, and, in some instances, to feed up the cutter to its work. But in the manufacture of the wheels and pinions still less is left to the judgment of the operative, for the larger portion of the cutting and shaping machinery is automatic. In England the custom is to revolve the work to be turned on dead centres in a hand lathe with drill bow and screw ferrule, and with a graver to cut away metal upon each down stroke of the bow, freeing the point of the tool during each upstroke. Such work can only be done surely after long experience, and with the exercise of great care to secure perfect truth. In America we see all turning of staffs, arbors, and pivots done by a sliding or engine lathe. Not such an one, of course, as is to be found in our engine works, or gun shops even; but a tool made to take a cut varying in length from one-twentieth to one half of an inch, and calculated to reduce diameters down to one two hundred and fiftieth of an inch. Such a machine, with an industrious girl to feed it, will make two thousand cuts per day.

The tools for the production of the teeth exhibit a marvellous advance upon those in use either in England or Switzerland. As is well known to all practical machinists, the controversy is an old and long one with respect to the form to be given to the teeth in geared work. English and Swiss horologists incline to the use of the involute curve, or to a compromise, while the Americans adopt wholly that of the epicycloid. But although the wheel cutter of the older countries may defend warmly the use of either curve, the nearest he can come to producing it in his work is to lay it off very large, and transferring it to a templet to serve as a guide to his eye, with graver and file, then to form his cutters so that they shall produce a curve that looks something like the one projected mathematically. Not so the American. He makes a machine in which he obtains the proper curve at once on his cutter laps, using the generating circles themselves as the initial point in the process. So he does away at once with the element of doubt, and instead of saying, "I think the teeth or leaves are such a curve," he can say, "The curves beyond the pitch lines are epicycloidal, obtained from their own generators." So also by his arrangement of machinery he can be sure that the division of teeth and spaces is the best which experience has taught, and that the radial undercut is nicely proportioned. But the machines in which the wheels and pinions are cut evince also a great advance over the modes in use among our old school workmen.

The old English or Swiss cutting engine with its universal index plate was an ingenious contrivance, and served its purpose, and may be useful for many years to come in the country jobbing shop, but it cannot hold its own in the Lancashire movement shops much longer. The power of indefinite and rapid reproduction is one which will be required, and which the tools spoken of are incapable of. The American wheel cutter is a tool which combines ease of handling with certainty of reproduction. By its use a girl can cut more wheels in one day than a skilled English workman can cut in three days, and can cut them better.

The machine spoken of is only an adaptation of the milling tool. It is very simple in its construction, care of course being taken to obtain close adjustments. It consists of a revolving spindle attached to a traversing bed, which can be worked by a rack and pinion attachment in connection with a lever arm. The blank wheels are placed on a "quill" at right angles to the revolving spindle, and at the base of the quill is secured a spaced disc or index plate having the same number of spaces as there are to be teeth to the wheel. The revolving spindle is pierced in a right line with the centre of the quill, to receive a cutter shaped to fit the space between two wheel teeth. The tooth cutting is effected by securing a stack of wheel blanks to the quill, revolving the cutter spindle very rapidly and traversing it so as to cut a groove through the entire stack. Raised again the stack is advanced one notch by means of the index at the base of the quill; another groove is made, and the operation is repeated until the whole circumference is fitted, when we find that we have made twenty-five perfect wheels in little more time than the Swiss could have made one. The fine adjustments of the machine render it capable of cutting teeth for a coarse train timepiece, or for the delicate high numbered train of a four or six-sized lady's watch. The English still use drawn wire for their pinions. One Lancashire gentleman has, we believe, lately attempted to cut them from the solid wire, but has met with such a storm of opposition from his workmen that he has desisted. The American pinion cutter is only an adaptation of the wheel cutter, using three small circular-shaped saws instead of one cutter, and operating one pinion at a time.

The tools used for finishing and polishing the pinions are simply an adaptation by machinery of the motions of the hand-worker, and by cam, eccentric, or connecting rod, we get all the beautiful polish which can only be produced by a perfect crossing of the lines of abrasion. Here also the grinding machine is used to reduce to absolute truth the hardened and tempered staffs of balance, pallets, and escape pinion.

In the manufacture of the escapement again there is to be found nothing of the uncertainty of the English workman; he knows nothing of the scientific reasons for making certain angles to his pallet stones, and could not prove to you mathematically that they were any certain angles. He has simply a set of gauges which have been handed down to him by the tradition of the elders, errors and all, and he grinds and files everything to these gauges. Not so with the machine-made escapement. The escapement laid off scientifically, the wheel will be found always the same, although cut in a very similar machine to the tooth-cutter already described, the only difference, indeed, being that it has several shaping tools instead of one only. The pallet angles must be correct, for the machinist made a tool by which only the two inclinations of the planes can be obtained. The pallet slots are assured in the same manner, for the little milling machine can only traverse in the right direction. So with the roller; turned to an exact size, the drill makes the ruby pinhole in a position which is constant in all of that size, and the grinding lap cuts the crescent to the same depth in each roller. The ruby pins, too, by an adaptation of the grinding machine, are produced of an uniform diameter.

The only other thing noticeable in this branch are the gang skives, which are similar in their arrangement to ordinary gang-saws, the difference being that they effect by diamond powder upon nodules of precious stone what the teeth of the saws effect in wood, namely, a severance into planks and posts.

The machinery used in the manufacture of screws is simple. The spring chuck lathe is used to hold the steel to be operated on. A Swiss slide rest carries the shaping cutters, and the thread is cut by an ordinary jam die. These dies and the standard taps are cut in a little gem of a lathe, which is only a miniature of the screw-cutting engine to be found in any ordinary machine-shop, and is capable of cutting up to 200 threads to the inch. The old slotting file, too, is not found here, the slits in the screw-heads being made by a circular saw which traverses a row of about a hundred at a time, thus effecting perfectly in the large number the work which the hand-worker takes a longer time to do imperfectly on one. The manufacture of flat steelwork calls for much the same kind of machinery as we found in the train room, adapted, of course, to the peculiar shapes it is to produce, the specialties of the department being found in the tools used to grind and finish the curved surfaces.

Compensation balances call for but little special machinery, the most noticeable being the index chuck, in which are drilled the holes for the adjusting screws, an arrangement which enables the operative to drill the twenty-two holes without removing the work from the lathe, and to finish in this manner 100 balances per day.

By the aid of self-measuring tools the jewelling of the watch movement is reduced from the specialty of a skilled workman to a job which may be picked up by any ordinary *employé*. It is painful to see the unnecessary labor expended under the English method in cutting and trying till the perfect fit is obtained.

The swing rest does away with all necessity for this, as it causes the cutter itself to determine the correct limits of its work. A fixed vertical arm is attached to a tail stock-bed, having at right angles to the top a nose on which may be placed the jewel or other article to be measured. Swung on a hinged joint also to the tail stock-bed is a spindle-cutter rest, pierced in a line with the lathe centre for the reception of the spindle, and carried the same distance beyond the lathe centre as that point is above the hinged joint. This extension is so made as to slide close over the fixed nose spoken of before, and the whole is so arranged that when the cutter-rest is swung close to a stop on the nose the centre line of the cutter is coincident with that of the lathe head. The action of the tool is obvious. If a jewel be placed on the nose and the rest be brought up close to it, that portion of the tool will be subtended a radial distance equal to the diameter of the jewel, and at the cutter line it will measure the radius of the jewel, and so will cut the hole the exact size required. This machine is found of infinite service in fitting up the watch, as it does away in many cases with the necessity for broaching holes to fit, and a traversing index-bed will permit, should occasion demand, a hole to be cut of any degree of taper. The pump centre lathes differ but little in principle from those to be found in the workshops of the Old World. But the jewel-opening lathes are very greatly superior to the Clerkenwell tools. They consist of a spring-chuck head-stock to hold the jewel and a revolving spindle for the copper opener. The arrangement of this machine insures a perfectly round hole, a result never certainly attainable under the hand method, and it also permits the employment of unskilled labor in what has hitherto been a most delicate operation. It is found expedient in the finer grades of work to give to each watch an individuality, and to make absolutely correct the distance between the jewel faces of the 'scapment work. To effect this an attachment is added to the swing-rest which enables the operative to make the plates and staffs self-measuring, and so to cut the shoulder on the jewel setting just the height necessary to give the staff .0006 of an inch and shake.

In the remaining branches of manufacture —those of dial making, gilding, and setting up—the processes are only such modifications as would suggest themseves to any large manufacturer, and consist chiefly of a minute division of operations. But not only do we find an advantage in respect of the watch-making tools proper, we find also very great superiority in the appliancess for making these tools. The use of labor-saving contrivances in America in all the avenues of trade has given rise to especial machinery for their production, and this is very noticeable in the watch factory machine-shop. The screwing and sliding lathes are made to meet more varied requirements than are the English articles. Planers, too, are capable of adjustments which are not attainable, except in very expensive machines, in England; and in small form, with a 4 in. or 6 in. stroke, we have as yet failed to find the machine. Another most useful tool, which is an absolute necessity to the watch machine shop, is the universal milling tool; and indeed no machinist can afford to be without it if he has once used it. Yet we can find in England no tool which can take its place, or which combines such a multiplicity of operations. It is adaptable not only for all ordinary milling, but it can be used to cut straight or spiral reamers, drills, and mills. It can be arranged to cut spur or bevelled gears and it can also be used to cut straight or spiral cones. The movement and feed of the tool-carriage is automatic, and it is provided with adjustments for any desired angle. Such a machine cannot but be a favorite with close workmen on fine work. A machine wholly unknown outside the watch factory is the parallel and cone grinder, a modification of course of the grinding tools now replacing the file in so many shops. This machine reduces to absolute truth and fit the hardened steel spindles and bearings which are the specialty of watch-making machines. By it any

taper given to the spindle may be reproduced in the bearing, sleeve, or collar, and the fit is at once removed from the region of doubt. Any desired degree of finish, too, may be attained, that usually preferred being by the use of diamond laps. So it will be seen that while the tools for the manufacture of watch-machinery are very fine, there is no lack of means for the production of highly-finished and perfect work.

The picture of this American machinery teems with lessons to the Englishman. To the machine-manufacturer it speaks very loudly. We must all bear witness to the marvellous beauty and finish of some of our English lathes, with their ingenious compound rests for the turning, etc., of shaped surfaces. But nowhere in England can we see such lathes as we find mounted on the benches of the watch factory; nowhere on this side of the Atlantic can we see tools so well made and closely fitted or provided with such multiplicity of adjustments for the close correction of errors resulting from wear or otherwise. This state of things is due alike to the lathes and men of the machine-shop, for the system has most certainly produced a set of workmen who are second to none as practical machinists, and, in all probability, cannot be equalled.

To the watch manufacturer it speaks very loudly, especially so in the present state of the trade, when a gentleman, who turns out 160 watches per week cannot increase his supply, cannot meet half the demand upon him, simply because he cannot get workmen, and apprentices take so long learning. Machinery, once made, is always ready, and is as good for twenty hours a day as ten. To the capitalist it speaks very loudly, in the face of an increasing demand, of which over 60 per cent. is met by the importation of an inferior French or Swiss article; and the capitalist must recollect, too, that the machinery is not an experiment, but an assured success, which is now paying 40 per cent. on the investment of capital, and that its use at once doubles the productive power of the operatives, for Clerkenwell takes over seventy hours to make a watch, while Waltham produces one for each thirty hours of labor.

To the intelligent public it speaks, offering reliable work at a cheap rate, and, in repairs, placing them beyond the reach of irresponsible and ignorant workmen, and making the duration of a valued watch not such a matter of uncertainty as at present. So we may ask the question, in all sincerity, which has often been made to us, Why does not England adopt the watch-making machinery of America?

SCIENTIFIC ERRORS.

From "The Architect."

Professor Tyndall recently demonstrated before a brilliant audience, that certain ideas which have been held for the last century and a half by all natural philosophers as to the power of the atmosphere to transmit sound are altogether erroneous. For more than a hundred and fifty years a statement has been repeated by one scientific writer after another, to the effect that the power of the atmosphere to transmit sound corresponded with its power to transmit light, or in other words, that the clearer the day the further could sound be heard, and the denser the mist, fog, or rain, the worse for the transmission of sound. This dictum, for which what passes as high authority could be adduced, proved entirely misleading when put to the test; so much so, indeed, that it would be hard to see how it can have escaped formal contradiction all these years, did we not know how very ready we all are to take for granted anything which a man with a name that carries weight says in an authoritative way. Sounds of great space-penetrating power, including the reports of an 18-pounder gun, which, on some occasions, were heard more than 12 miles out to sea, proved during the Professor's experiments, inaudible on many clear days at distances varying from 5 miles to 2, the weather being on those days fine and sunshiny. The true nature of the impediment which thus shortened the range of hearing was traced out, and proved to be the presence in the atmosphere of innumerable strata of heated air and invisible vapor ascending from the surface of the sea, heated as it was by the rays of the sun, falling with powerful effect upon it. With this explanation, however, we have not much to do at the present moment, though it is not impossible that some important

light might be thrown by the learned Professor's remarkable experiments upon the condition of the air within a public building, and its power to transmit sound. We simply refer to the circumstance as a notable example of the necessity for bringing all scientific statements to the test, and repeating the experiments till there can be no doubt that the facts, which they are supposed to establish, really exist. And we further ask—if this misconception can have gone on so long unchallenged, and almost unsuspected, may there not be ideas, at least as erroneous, which pass current respecting the science of building? Have we no theories of construction with respect to which, a short but searching investigation would prove the mistake to be, at least, as great as that which it has recently fallen to Professor Tyndall's lot to correct?

We believe ourselves to be well furnished with data from which to compute the strength of timber, stone, brick, iron, cement, and all the materials upon the use of which depends the stability of our buildings; but it is not going too far to assert that, except, perhaps, in the case of iron, no experimental data, worth dignifying with that name, exist, and it is doubtful whether such trustworthy information as has been obtained as to some of the properties of iron, has been applicable to any extent to its use for the builder's purposes. We know, indeed, a great deal about Destruction. The range, the initial velocity, the penetrating powers, and the crushing effect of missiles of all classes hurled from every description of gun by the force of every possible explosive, have been tested accurately, and the strength and quality of the armor plating sufficient to withstand each description of butt attack, have been determined with precision; how about the arts of Peace? We know pretty well what iron will do in the way of destroying life; but most of the work in which that material is used to protect life is done in a rule of thumb kind of way, and proceeds upon no exact application of the results of the scientific investigations which have taken place; while as to those very investigations, when we come to ask whether they were searching, exact, repeated till the possibility of serious error had almost disappeared, and tried on such a scale and with such apparatus as would insure accuracy, we find much to disturb our confidence.

The testing machine employed by Mr. Anderson, whose popular work on the strength of materials is perhaps the best, as it is certainly the most readable of all works on such subjects, is described by him, and proves to be one of very convenient application to small specimens, but it is not capable of taking in large ones, and it is only equal to exerting a force of 25 tons as a maximum. Probably the work done in this machine is fairly registered, but if we turn to experiments where a greater power has been wanted, we find that in all of them hydraulic rams have been employed, in the use of which the force is estimated by a pressure gauge; but "however carefully"—these are Mr. Anderson's own words—"pressure gauges may be constructed, they are liable to alteration and error. In addition, when the load has to be calculated from the pressure in the press cylinder, the friction of the ram must be allowed for, and this cannot be done with any great accuracy."

The condition of matters is in short this. We possess formulæ for the strength of timber, calculated upon the behavior of specimens not much larger than sticks of firewood, and formulæ for the strength of stone, calculated upon the basis of bits fit for use as paper weights or cabinet specimens. We have tried experiments, but we are quite unable to say how far the known inaccuracy of the usual testing machine has interfered with our results; and we have trusted to a few trials, and those with small pieces of material, without being able to say how far the analogy holds between the strength of a stick whose bearing is measured in inches and that of a beam whose bearing is measured in feet.

There is some reason for supposing that small specimens of stone may give a result not very disproportionate to that given by large blocks; but we know of no published results to prove it. There is, on the other hand, strong reason for believing that the strength of timber in the log is not at all in proportion to that of timber cut into small specimens, but this surmise has to be gathered rather from the experience of failures in the use of timber, than from any scientific inquiry. We may find it prudent to give a large excess of strength wherever we can, for the sake of securing stiffness and avoiding risk; but there are occasions where every constructor has to reduce some part of his construction to what he believes to be near its minimum safe strength; and

on such occasions the painstaking architect or engineer is often oppressed with a vague sense of apprehension, if he attempts to satisfy himself as to the solid basis upon which has been built up the plausible and complete series of formulæ offered for his acceptance in the usual books of tables.

It is with a view to show the way out of these uncertainties that the Committee for arranging that part of the London International Exhibition of 1874, which relates to building materials and appliances, have unanimously decided that it is most desirable to conduct a series of experiments upon building materials on a scale, and with an accuracy, sufficient to insure trustworthy and useful results. They do not of course propose to settle all questions of construction, or perhaps even to dispose of any; but they propose a specimen series of experiments, such as should show what can be done with materials in common use, and of dimensions such as constantly occur in buildings. They propose to exhibit the materials after they have been broken in the testing machine; and to publish an accurate record of the weight under which they failed, and of their behavior during the previous stages of the experiment short of their failure.

For this purpose the magnificent testing-machine of Mr. Kirkaldy, is now available. The principle applied in that machine is that described by Mr. Anderson, the authority already quoted, when he says:— "The best kind of hydraulic machines are so contrived that the precise force which is exerted by the water is shown by a delicately-adjusted steel yard." Specimens of great length and large scantling can be taken into this machine. The powerful force available is equal to the destruction of these specimens, and the construction of the registering arrangement is such as to indicate with perfect accuracy the force exerted at any moment, and the deflections it occasions. The Committee have accordingly recommended the use of this machine in the proposed experiments, and have drawn up a list of what experiments they would like to try should the funds be obtainable. They wish to expend £500, and they hope that the Royal Institute of British Architects, the Institution of Civil Engineers, and the Society of Arts might be induced to vote money towards the expense. It is to be presumed that the Committee have been encouraged to understand that Her Majesty's Commissioners would also contribute liberally towards an undertaking which, if well carried out, will go far to render their exhibition interesting to every person connected with architecture, engineering or building.

We have before us, as we write, a list of all the suggested experiments. It is printed for private circulation only, and we do not feel at liberty therefore to transfer it to our columns; but we may venture without indiscretion to give such a general idea of its nature as to say that it includes the behavior of large beams of various woods under breaking and under thrusting strains; the behavior of rolled iron joints, flitch girders, stone steps, and stone landings under breaking strains; the behavior of stone columns and cubes of stone (from various quarries and variously bedded) under thrusting strain; the resistance of piers of brickwork, and of bricks of many different kinds, to a similar strain; and the resistance of cement to a tensile strain. It is proposed to try not fewer than three similar specimens of each sort, and the total number of single experiments appears as if it would considerably exceed two hundred.

We can only say that this proposal has our cordial approval, and that we sincerely hope the necessary funds will be forthcoming. It will of course best conduce to a valuable result if the materials to be tested, or the bulk of them, are such as are procurable by builders in the way of trade, and purchased in the open market, not selected specimens such as would be submitted for exhibition. This has probably been contemplated in the estimate. At any rate it ought to form part of the scheme, for if no timber but the very strongest, no stone but the very choicest, and no iron but the very finest be tried, we shall still be as far as ever from knowing what strength we may fairly expect to find, if, in an ordinary building carried out in the usual manner by a builder who has gained it in competition, we employ a beam or a column of the same scantling as in the Committee's experiments.

It would be well worth while if the Institute would encourage experiments by keeping a record of tests undertaken by its members, and publishing the same from time to time. It would be especially valuable if a good series of failures could form part of this record, and though there is often difficulty in obtaining the accounts of such disasters as are not accompanied by

loss of life, still they are to be had, and they are eminently instructive. For example, the two most ambitious timber roofs erected in London within the last five-and-twenty years have both failed. We allude to the collar-beam roof at the South-Eastern Station, London Bridge, and the laminated rib roof at the Great Northern Terminus, King's Cross. There ought to be no great difficulty in obtaining exact accounts of how they failed, and why? There is no secret about their having been unsuccessful, and in each case the reputation of a living architect would not be affected. These, therefore, would be good examples of failure, and such as might fairly be published. Examples of tests are not of frequent occurrence, but even now they are carried on from time to time; they deserve every possible encouragement, and no more useful course could possibly be taken than to put them on record. It is, therefore, with great pleasure that we have seen this proposal on the part of the Exhibition Committee, and we feel sure that, if carried out, the experiments, and the published record of them, will be equally valuable as examples, and acceptable on their own merits.

FOUNDATIONS UNDER WATER.*

By GABRIEL JORDAN, C. E.

Within the last three years, the writer has had occasion to construct a bridge for the Mobile and Montgomery Railroad Company, across Tensas river, in the State of Alabama. The substructure consisted of 12 piers of 2 cylinders each, and a draw-pier of 8 cylinders; the superstructure was composed of 12 spans of 152 ft. each, and a draw-span of 260 ft., on the plan of a triangular truss (Fink's improvement).

Tensas river is the largest of the many outlets or bayous of the Mobile river; it is 2,100 ft. wide, and from 16 to 35 ft. deep, with a daily tidal action of only about 16 in. The bottom of the river to a very great depth is formed of a light shifting sand, subject to deep and troublesome scouring with the slightest contraction or disturbance of the water-way.

The means of the railroad company were too limited to admit of the pneumatic process, and other plans practised in this country presented the double objection of expense and tendency to produce serious scour. After carefully investigating all the conditions incident to the work, it was determined to use wooden pile piers incased in cast-iron cylinders.

The piles were driven in two clusters of 12 piles each, the cylinders were then lowered over them and filled with concrete—the whole work presenting very much the appearance of the ordinary pneumatic piers built in many parts of our country. The piles were driven to a depth of 30 ft. into the sand, with an ordinary floating steam machine. The first pile in each cluster always drove with ease, and would yield from 2 to 3 in. under the last blow of the hammer; but as the number of piles increased, the resistance increased in a rapid ratio, until no appreciable effect could be produced on the last pile of each cluster, after reaching the required depth. After the driving of each cluster was complete, the piles were thoroughly bolted together with 1¼-in. bolts, and all sawed off near the surface of low-water.

The cylinders (6 ft. in diameter, 1¼ in. thick, in sections of 10 ft., connected by inside flanges and bolts) were lowered into position over the piles to the sand bottom. The work of handling the cylinders was all done from a floating derrick, with heavy blocks and lines and the portable engine used in driving the piles.

Attached to the derrick boat was a small rotary pump, taking its water through a 4-in. suction pipe immediately from the river, and run at a speed of from 200 to 300 revolutions by the same engine used for the other work. The discharge pipe was made of very heavy canvas hose, 3 in. in diameter, about 50 ft. long; it led to a cast-iron cone about 10 in. in diameter, from which radiated 12 gas-pipes, 1 in. in diameter and about 2½ ft. long. At the end of each of the 12 short pipes was attached a right-angled elbow, and to each was connected a pipe leading down into the cylinder to be sunk. These pipes were made in sections about 10 ft. long, so as to lengthen them to any extent, according to the depth of work required. This little appa

* Transactions of the American Society of Civil Engineers.

ratus was lowered and raised at will, with a light block and line. As soon as the pipes were lowered into position on the sand, and the pump put in motion, they would sink with great rapidity, very often falling as much as 10 and 15 ft. at a single impulse. The sand would at once be put in an active state of ebullition, thus destroying the friction, and the great cylinders would quietly and sometimes quickly sink to the required depth of 15 ft. below the bed of the river. The movement of the cylinders was not uniform, but varied with the nature and density of the material passed through; it often required several hours to sink one a single foot. In sinking a cylinder of 4 ft. diameter, in the draw-pier, under the immediate supervision of the writer, it was carried to a depth of 14 ft. in about two hours; the remaining foot was overcome only after 5 or 6 hours' hard pumping and labor. The resistance came from a small deposit of clay, which was finally removed or scoured away by using a single pipe and jet of water on the outside of the cylinder.

While sinking one of the large cylinders, the engineer in charge telegraphed to the general office, that he had encountered a car-wheel about 2 ft. under the sand, which had been used as an anchor for a buoy, and that he had no appliances for removing it. While a plan for relief was being considered, and within less than one hour's time, a second dispatch was received announcing the fact that a single pipe and jet had been passed through the hub of the wheel which thus had been pumped 16 ft. below the surface of the sand, entirely out of the way.

All the fixtures for doing this heavy work were of the rudest character, and very inexpensive—everything was done from the decks of two ordinary flat boats, without staging of any kind. The derricks, pumps, and other appliances were of the simplest construction, because the contractor had serious doubts as to the success of the plan, and was unwilling to incur the expense of efficient and well-designed machinery upon an uncertainty. He commenced and carried the work to a successful completion without addition to his immature contrivances.

After the cylinders were sunk to grade they were filled with good shell concrete, deposited through a tube, used somewhat after the manner frequently described in connection with other works in this country; after shrinkage and refilling, a heavy cast-iron cap was bolted over the top of each cylinder, and the piers were complete for the superstructure.

These piers have now been in use about eighteen months, and so far have given entire satisfaction. A uniform scour of about 6 ft. occurred at each pier, in curve shape, extending some 20 ft. from the pier; beyond this distance there was no appreciable disturbance. The bottom around the piers was restored to its normal condition by filling the curve with broken stone.

It is not claimed that this process for sinking cylinders or piles can be advantageously applied under conditions differing very materially from those existing at Tensas, as the resistance was found quite difficult to overcome, when small deposits of clay were encountered; and in the event of striking logs or other hard substances, not discovered before locating the piers, the process offers no reliable plan for removing them Neither is it claimed that the process is new, for it is well known to the profession that many years ago an English engineer resorted to this method of sinking cast-iron piles in the piers of a bridge built over the river Leven for the Ulverstone and Lancaster Railroad Company. During the late war between the States, the Confederate engineers successfully used the process in sinking heavy wooden piles in the Bay of Mobile. In many instances these piles were driven 10 and 15 ft. in the short space of one minute, through a material that could not be penetrated by piles driven in the usual way.

It is believed this method of sinking large cylinders has never before been employed or considered to any extent, and it is now brought before the Society in the belief that it is susceptible of great improvement and enlarged application, and that it is peculiarly valuable because of the rapidity with which piers may be sunk with it.

DISCUSSION.

Mr. Macdonald—The piers, described in this paper, are identical in all essential respects with those invented by the late Samuel B. Cushing, member of this Society, and first introduced to practical notice in the bridge at India Point, Providence, R. I., in 1868. A full description of the method of construction is contained in a pamphlet issued by Mr. Cushing in 1870.

It will be observed that those piers consist of a cluster of timber piles, driven as closely together as possible, in the form of a circle, and enclosed by a cast-iron cylinder, into which is poured a sufficient quantity of concrete to fill all intervening spaces, and completely cover the tops of the piles, the better to protect them from decay above water, and the action of worms below.

We are thus particular in describing the essential principle involved in the use of these piers, as it would appear from the care taken to overcome the difficulties in sinking the encasing cylinders that they, and not the enclosed timber piles, contributed the controlling feature of interest to the undertaking. For all purposes of immediate stability, these cylinders might have been omitted. Their sole object as claimed by the inventor, is by means of the concrete filling to protect the timber piles from decay or deterioration, as must be evident from the present example, when they were driven but 15 ft. into a shifting sand, and rested upon the same material.

We do not agree with the writer of this paper that this system cannot be advantageously used under conditions differing materially from those existing at Tensas—the reason he assigns being that it is difficult to sink the cylinders when deposits of clay are encountered. From what has been said of the office performed by the timber piles, it will at once appear that a stiff clay bottom is peculiarly adapted to the placing of Cushing's pile piers. Into such material, clusters of piles may be firmly driven precisely as he has described at Tensas, and the encasing cylinders may then rest almost upon the surface of the bottom, or at most be settled into it a foot or two by their own weight; an additional security is obtained by placing a few feet of rip-rap around the base of the pier. In the case referred to, at India Point, the cylinders were worked into the mud bottom only about 7 ft., and at the Connecticut river bridge a still smaller distance.

THE FIRELESS LOCOMOTIVE.*

By RICHARD H. BUEL.

From "The Engineering and Mining Journal."

The New York "Tribune" recently, in calling attention to an article on the Fireless Locomotive, said that the inventor of this machine seemed to have taken council of Mrs. Partington, who inquired why they didn't boil their water at home, instead of using these dangerous steam boilers. Considerable attention seems to have been directed to the action of the fireless locomotive of late, and some remarks on the subject may not be devoid of interest. It was patented by Dr. Emile Lamm, of New Orleans, about a year and half ago, and locomotives designed in accordance with his patents are now in regular use on one of the railroads in that city. Two experimental locomotives have been built in this vicinity, and accounts of their trial trips have appeared from time to time in the daily papers. Dr. Lamm was a dentist, without any special education or experience as an engineer, but he devoted considerable time to experiments on prime movers that could be attached to ordinary street cars, in the place of horses. He was desirous of inventing a machine that would be cheap, compact, safe, and easily managed. Unwilling to accept the results obtained by previous experimenters, he put all his ideas to the test of practice. His first attempt was with an electro-magnetic engine. He afterwards experimented with ammonia, and his third plan was to employ a reservoir of water immersed in a tank of chloride of calcium at a high temperature. It was while conducting these latter experiments that he observed that the reservoir of water alone retained its heat for a long time, and as there were many practical difficulties in the use of the chloride of calcium, he finally decided upon the plan which is embodied in the present design of the fireless locomotive.

As now constructed, this consists of a reservoir, or tank, capable of sustaining a high pressure, mounted on wheels, and connected in the steam space to an ordinary

* A paper read before the Polytechnic Branch of the American Institute.

form of steam engine, the exterior of the reservoir (the steam pipes and cylinders) being protected by coverings from loss of heat by radiation. This reservoir, being partially filled with water, is connected at the lower portion to the steam space of a stationary boiler, and steam is admitted, heating the water and equalizing the steam pressure in the boiler and reservoir. The locomotive is then ready to start, and, if steam is admitted to the engines, will continue to move until the water in the reservoir has cooled down so much as not to be capable of furnishing steam of a working pressure. Suppose, for instance, that on starting, the water in the reservoir has a temperature of 400 deg. Fahrenheit, and that at the conclusion of the run its temperature is 250 deg., corresponding to pressures of about 235 and 15 lbs. per sq. in. above the atmosphere respectively. In this case, each pound of the water would give up 150 units of heat, and each pound of water that was evaporated would require about 970 units of heat for its conversion into steam, so that each pound of water in the reservoir would give out heat enough in cooling down, to make about 0.16 lbs. of steam, or a little more than a cubic foot.

This, in brief, is the theory of the fireless locomotive. It is hardly necessary to point out the advantages of this system. It must be evident that the reservoir, which is not exposed to the action of fire, will probably be more durable and less liable to rapid deterioration than an ordinary boiler. The danger of explosion, when the machine is in motion, is very slight, as the greatest pressure is put upon the reservoir when it is being charged at a station, and this pressure is continually diminishing during a run. There is little chance of danger from the oversight of the attendant, and less skilful engineers being required than in the case of ordinary locomotives, the running expenses can be reduced. In many places where motive power is desired for cars, it becomes a serious question how to dispose of the products of combustion, so that they shall not vitiate the atmosphere. The fireless locomotive solves this problem admirably. It may be that this system is not quite as economical as that in which the steam is generated by the combustion of coal in each separate boiler, and probably this can only be determined by experiment. But by having well designed stationary boilers and careful management at the stations where the reservoirs are charged, it is possible that there will not be much difference in the cost of fuel, between the two systems. In the matter of relative bulk, of course, the preference is to be given to the coal-burning locomotive, since a good boiler is capable of utilizing about 10,000 units of heat from the combustion of a pound of coal, and in the example cited above, the reservoir utilized 150 units from each pound of water. This is not a matter of so much importance, however, in many cases, as some of the other points in which the fireless locomotive seems to possess advantages.

The writer, in company with Mr. Henry L. Brevoort, recently made a trial trip with the smaller of the two locomotives in this vicinity. By the courtesy of the officers of the Company, and particularly through the exertions of the engineer, Mr. Gibson, arrangements were made to take down considerable data. It was impossible, however, owing to the defective nature of the connections, to determine accurately the temperature of the water in the reservoir, or to observe the variations in the water level. It was found that the water was quite unequally heated in different portions of the reservoir, showing that the arrangement for charging with steam was not as complete as was desirable. On starting, the reservoir was half full of water, but the glass gauge having broken, no further observations could be made. A counter was attached to the engines, and the steam gauge was carefully tested before the trial. The run was made from East New York to Canarsie, and back. During the trip, indicator diagrams were taken from the cylinders, in sufficient number, and under such circumstances, as to give average conditions. It is believed, therefore, that the data, although not as full as could have been desired, are quite accurate, and give the fullest particulars of the practical working of the fireless locomotive, that have yet been obtained.

The locomotive with which the trial was made, consists of a platform set upon a four-wheeled truck, carrying a cylindrical reservoir, 37 in. in diameter and 9 ft. long, with a steam dome, 12 in. in diameter and 2 ft. high. The shell of the reservoir is $\frac{1}{4}$ in., and the heads $\frac{5}{8}$ in. in thickness. No braces are used in the construction. The steam drum is connected to a pair of

vertical engines, fitted with the link motion, each cylinder being 5 in. in diameter by 7 in. stroke. The reservoir is covered with cement and felting, and the steam pipe and cylinders are also felted. The engine shaft has a pinion of 26 teeth, gearing into a wheel of 46, which latter is secured to one pair of truck wheels, which are the drivers. In charging the reservoir, steam is admitted through a two-inch pipe, running the whole length of the reservoir, and perforated with small holes. The dimensions of the reservoir and cylinders, in cubic feet, are as follows:

Cylindrical portion of reservoir	64.64
Steam dome " "	1.55
Volume of cylinder swept through by each piston, per stroke	0.0786
Clearance and passages, at each end of each cylinder	0.0045

At the commencement of the trip, the pressure of steam in the reservoir was 142 lbs. per sq. in., and at the conclusion it was 22. During the run, the variations in the pressure were as follows:

3.35	142
3.37	132
3 38	124
3.39	124
3 51	102
3.53	97
3.55	89
4.04	70
4 07	66
4.10	52
4.13	48
4.15	44
4.21	29
4.24	22

81.5 mean pressure during run. Several short stops were made during the run, for the purposes of observation and adjustment, and the power exerted by the engines at different points varied considerably, on account of changes in the grade of the road. The total time of trip was 49 min., and the running time 35½. The total number of revolutions of the engine was 5,233, and the average revolutions per minute 147.4. The distance run was 4.4 miles; and average of all the indicator diagrams shows that the mean pressure of steam above the atmosphere, in the cylinders, was 23.01 lbs. per sq. in., and the mean back pressure, 5.15 lbs. The diameter of the piston rods being ¾ of an in., the mean area of each piston is 19.414 in.—and from these data it is found, by a simple calculation, that the mean indicated horse-power exerted by the engines during the run was 3.61. Knowing the volume of steam required for each stroke and the total number of strokes, it appears that the amount of steam accounted for by the indicator was 1739.4 cubic ft. Owing to a faulty construction of the valve motion, it was necessary to run with full link, and regulate the speed of the engines by throttling the steam, so that the steam was wire-drawn, instead of being expanded. The mean terminal pressure of the steam above the atmosphere, as shown by the indicator diagrams, was 19.86 lbs. per sq. in., and as steam of this pressure weighs 0.0846 lbs. per cubic ft., the amount of steam furnished by the reservoir, accounted for by the indicator, was 147.15 lbs. The amount of steam actually used by an engine, however, is generally in excess of that shown by the indicator, and as the protection of the reservoir from loss by radiation was far from efficient, it is probable that the actual evaporation was somewhat greater. It will be easy to calculate how much water would have been evaporated under the most favorable circumstances, viz.: that no heat should be lost by radiation—that the water in the reservoir should be heated, at starting, to a temperature due to a steam pressure of 142 lbs. per sq. in., and should be saturated with an equal volume of steam at that pressure, and that, at the conclusion, the water in the reservoir should have a temperature due to a steam pressure of 22 lbs. per sq. in., and should be saturated with an equal volume of steam at that pressure.

It will be fair to assume the evaporation to take place at a pressure of 82 lbs. per sq. in., a mean between the initial and terminal pressures in the reservoir. Then, at starting, the reservoir would have 1,236.3 lbs. of water, each pound of which contained 361.8 units of heat, and 23.2 lbs. of steam, each pound of which contained 1,224.3 units of heat—so that the total number of units of heat in the reservoir at commencement would be 475,696.6. At the termination there would be 1,236.3 lbs. of water less the amount that had been evaporated, each pound containing 262 units of heat, and 5.92 lbs. of steam, each pound of which contained 1,193.8 units of heat—and calling x the amount of water that had been evaporated, the number of units of heat at termination would be 330, 956.48—262x. The number of units of heat available for making steam would be the difference between the number of units

at commencement and termination, or 144, 740.12+262x. Each pound of water that was evaporated would require an addition of 951.1 units of heat for its conversion into steam—and by the solution of a simple equation it is found that the number of pounds of water that would be evaporated, is 210.04.

The reasons for the difference between this result and 147.15 lbs., as calculated from the indicator diagrams, have already been given—and it seems probable that the actual evaporation in the reservoir was about mid-way between these two results.

It will perhaps be a matter of surprise to many, that the working pressure of steam in the reservoir was exhausted in so short a time, and may cause doubts as to the value of this system of locomotion. It should be remembered that the general design and construction of the fireless locomotive that has been described, seem expressly intended to render the best system unsuccessful. It may be worth while, then, to devote a little space to a consideration of the engines. From the evaporation, as shown by the indicator diagrams, it appears that the amount of water required by the engines per indicated horse power per hour, was 68.9 lbs. or 1 1-10 cubic ft.; as already remarked, it is probable that still more water was used. In the time of James Watt, an evaporation of 1 cubic ft. of water an hour was considered a liberal allowance for the production of an indicated horse power in an engine—and the use of so much steam in these engines is evidence of bad design or improper management. It will not be difficult to find reasons for this great waste.

Referring again to the indicator diagrams, it will be seen that the back pressure on the pistons was 22.38 per cent. of the mean pressure in the cylinders. By far the greatest waste occurred, however, from wire-drawing the steam, instead of cutting it off at a proper point, and allowing it to expand during the remainder of the stroke. No argument is necessary to show that an automatic cut-off would be the most economical arrangement for an engine working with a continually varying pressure of steam. A comparison of the average conditions in the two cases—1st, that steam of 81.5 lbs. pressure should be cut off at such a point as to produce a mean pressure of 23.01 lbs. per sq. in. in the cylinder—or 2d, that steam of the same initial pressure shall be allowed to expand without doing work, until its pressure is reduced to 19.86 lbs. per sq. in., the terminal pressure—shows that the waste, in wire-drawing the steam is 99 per cent.—or that, in the case under consideration, if the steam had been cut-off, it would have produced the same effect with an expenditure of 50.25 per cent. of the amount of steam actually required. Hence, with this single change in the arrangement of the engine, all other things remaining the same, the locomotive would have run twice as far.

A new locomotive is now in course of construction, in which more efficient arrangements are made for heating the water when charging the reservoir with steam, a better system of valve gear is applied, and the general design and workmanship are much improved. It is hoped that this machine will demonstrate successfully the merits of Dr. Lamms' system.

It may be interesting, in conclusion, to consider the case of a fireless locomotive under more favorable conditions, but under such as it is believed can readily be realized in practice. Suppose, then, that a reservoir of the same size as the one which has already been described, is filled to the dome, on starting, with water having a temperature due to a steam pressure of 275 lbs. per sq. in., and saturated with an equal volume of steam at that pressure,—that, at the termination, the water is saturated with an equal volume of steam having a pressure of 20 lbs. per sq. in., and has a temperature due to that pressure—that the engines shall be so designed as to develop 4 useful horse power with an indicated power of 5 1-3 (making an allowance of 25 per cent. for friction), using 25 lbs. of water per indicated horse power per hour—and that there shall be a loss from radiation of 5 per cent. of the water evaporated.

Under these conditions, the reservoir would contain, at the commencement, 1,499,754.66 units of heat, and at the termination, letting X represent the number of pounds of water evaporated, it would contain (905,913.82—258.7 X) units — so that there would be (584,840.84+258.7 X) units of heat available for making steam. Each pound of water would require an addition of 966.4 units for its conversion into steam, so that the amount of water evaporated would be 826.4 lbs. The loss from

radiation would be 41.12 lbs., and the steam available for useful work, 785.28 lbs.—hence the locomotive would run 5.9 hours before the reservoir required recharging.

It is believed that the foregoing is a fair statement of what may be expected from this locomotive, when properly designed and constructed.

SOLUTION FOR THE BATTLE OF THE GAUGES.

By LEWIS M. HAUPT.

Written for Van Nostrand's Magazine.

FACILITY OF COMMUNICATION IS ONE OF THE MOST IMPORTANT ELEMENTS IN HUMAN PROGRESS AND MATERIAL DEVELOPMENT.

It must be conceded that since a straight line has neither breadth nor thickness, it is the limit of narrow-gauge railways; consequently any road in which the two rails are made to approach each other until their separating distances is zero, that is, until they coincide, must be the *ne plus ultra* of narrow gauges.

That the idea of a zero gauge railway will share the fate of all other important inventions and improvements, in meeting with the popular incredulity, is to be expected, but that it is entirely practicable has been already demonstrated. It is the object of this paper merely to state the facts as they exist, and not to attempt in such limited space and time a satisfactory solution of the problems of cost of construction, repairs, rolling stock, equipment, limits of grades and curves, stability, speed, tonnage, etc.

It will be apparent from a mere description of the road bed and rolling stock that an immense economy will result from its introduction or substitution, that it will render accessible districts which have heretofore been regarded as worthless for lack of communication, and that the degree of its curvature may be so great as to render it absolutely a surface line in a very broken country.

The combination of two rails results in a single "crescent" rail having a weight of about one-fourth that of the two rails ordinarily used, thus reducing the cost proportionally. This rail surmounts the upper edge of a horizontal prism, the right section of which is a right-angled triangle, resting upon its hypothenuse as a base. Dimensions—altitude 12 in., "base 24 in.," area 1 sq. ft. This triangular prism is the trunk or road bed, and may be laid upon the natural surface, supported upon unhewn posts resting on a sub-foundation below frost, or may be elevated to a height of several hundred feet as in crossing deep ravines or gorges. In excavation, therefore, on side hill, the base need be only 2 ft., in through cuts from 10 to 12, to clear the cars and allow side drains, and in embankment or trestle, 2 ft.

The prism may be constructed either of timber, 1 ft. square, cut through its diagonally-opposite edges and turned over back to back; of a square cone of smaller cross section, covered by a 2 or 3-in. plank, spiked on to give the requisite lateral surface (1.4142), or of 1-in. boards, placed vertically, and nailed to a 3-in. plank as a cone (the requisite level being given by templets). This last form is preferred, as distributing the flaws and joints in the best possible manner, and enabling curves to be turned more readily. The top surface may be protected by cement, paint, or metal covering, as desired.

The rail and trunk are united by spikes or bolts, in the ordinary manner.

Such is the roadway.

Fig. 1 is a section of the roadway and rail.

Fig. 2, an elevation of the same.

This construction requires a corresponding modification in the rolling stock, which has been effected as follows: Instead of the ordinary 4-wheeled truck, one of 2 wheels is substituted, in which these wheels revolve in the same vertical plane, fore and aft, as in a velocipede. These are the drivers or traction wheels which bear on the rail T, and to which the power is attached. Fastened to the bed of the truck and on both sides of the drivers are two axles fixed parallel to the planes (*s s*) by hangers. These axles carry at their lower extremity a cylindrical roller or guide, bearing on the planes *s s*, and at the upper end two conical wheels or guides bearing upon the sides, *t t*, of the rail, and also upon the drivers to prevent the latter from oscillating and thus injuring their journals. The number of drivers may be increased *ad libitum*, thus distributing

the weight over any desired length of track. The friction upon the guides is very slight, and varies inversely as the velocity, so that at high rates on straight lines it is practically zero.

Thus, it is seen that, although the centre of gravity is above the point of support, the case is not one of unstable equilibrium, for the base between the guides is 2 ft., which is distributed by the hangers to a bed of 4 ft. in the engine and 7 in the cars.

In the car trucks the wheels project through the axis of the floor, being covered by the seats, which are placed longitudinally, giving side aisles. By this means the floor may be placed as low as the rail itself.

These comprise the principal feature of the improvement, subject to modification to suit requirements.

The objection almost invariably urged is the fear that the rolling stock will run off

FIG. 1.

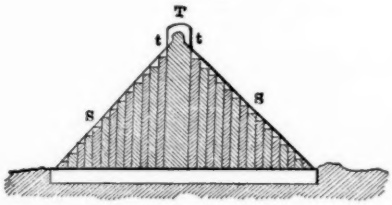
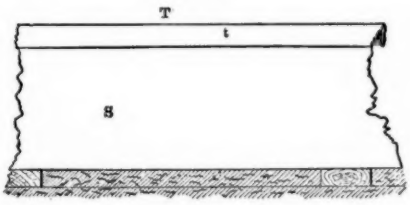


FIG. 2.



the track. It will be perceived that to do so the guides on one side must rise at least 1 ft., lifting the weight of nearly one-half the engine or car. This it cannot do, loaded as it is, and the greater the load the greater will be the stability. The only cause for derailment would be from rupture of the guides on the same side, but if their number be increased to three or four, it may never happen that they will all break simultaneously.

The illustration by the inventor, Mr. E. Crew, in his lecture before the Franklin Institute, on the 29th of January, would satisfy the most incredulous on this point. He had a circular prismoidal track of about 4 ft. diameter, constructed as a model. Upon this track he placed a model truck, and having mounted the track upon a vertical axis by giving a circular undulating motion to it, caused the truck to fly around with such rapidity as apparently to shoot across the diameter with greater velocity than a shuttle in a Jacquard loom. This, in itself, was perfectly satisfactory, but the inventor went still further; removing the track from its support and holding it by means of two handles, he gradually inclined its plane to that of the horizon, at the same time keeping up the oscillation so that the truck ran around as before, until it became absolutely vertical, and the truck did not fall off, proving that the force of gravity was neutralized by the inertia of the moving body, as in the gyroscope. A 4-ton engine has run upwards of 300 miles at the Chestnut street rink, in Philadelphia, on a track more than half of which is on a curve of 37 ft. radius. The question of practicability is therefore placed beyond a doubt, and it only remains to add a few words concerning its applications.

As an elevated street railway, it can have no superior, either for economy, quietness, safety or speed. It is admirably adapted to train-towing on canals, filling all the requirements of steam towage with much less power, and without waste or injury to the canal. It may be used as a camel in hydraulic engineering, but its most extensive application will be in mining districts, which are now destitute of the necessary transportation to develop them, or to lumber regions beyond the limits of a paying haul by wagons.

It is destined to become a powerful auxiliary in the hands of railroad corporations as feeders to their trunk lines, and a boon to property owners whose estates lie in districts inaccessible to ordinary railroads.

The cost of construction per mile can be readily computed for different districts from the data given. The simple mechanical details of switching, sidings, crossings, etc., have been satisfactorily arranged, leaving nothing doubtful in the way of its successful introduction.

It will be found of inestimable value to the railroad interests, not only of this country, but of the world.

AN ACCOUNT OF THE ERECTION OF A DRAWBRIDGE WITHOUT FALSE WORKS.*

By C. S. MAURICE, C. E.

In giving the following I would say, by way of preface, that though the matter may not be of sufficient importance to be made the subject of a formal communication to the Society, or to be embodied in its Transactions, yet the fact that the plan of raising was hastily improvised with only the crudest materials at hand for its execution, may serve as some apology for occupying a portion of your time this evening.

The structure to which I refer is the iron bridge built for the Alabama Central Railroad over the Tombigbee river, some six miles below the town of Demopolis. The width of the river here is from 500 to 600 ft. between its banks, and the depth of water varies from 6 or 8 ft. in dry seasons to 60 or 65 ft. at the time of heavy freshets. The first railroad bridge at this point was completed in 1866, and consisted of 2 Howe truss spans of 200 ft. each, and a pivot span of the same dimensions, the whole structure being supported on timber piers. In the substructure of the new bridge, which was built on the site of the old one, brick piers with stone copings were used, and the superstructure consisted of 2 fixed spans of 160 ft. each, with a pivot span of 260 ft., all of wrought-iron.

The construction of the new piers was begun in the summer of 1872, by Col. M. B. Prichard, of Montgomery, Ala., and completed about December 1st following. The contractors for the superstructure, who also removed the old bridge and furnished false work of sufficient strength to carry the trains while the work was in progress, began operations late in October, 1872. The fixed spans of the old bridge were taken down, and the iron spans erected in their place in the usual manner. This occupied till the first week in December, and the river being then at its extreme low-water mark, and with every prospect of continuing so for at least a month to come, the trestles were erected under the old draw for its removal, and by the middle of the month the contractors were ready to begin the erection of the new pivot span.† A heavy rain, however, having set in a few days before, it was deemed advisable to see what its effects would be on the river before trusting the iron upon the false work. The storm continued without interruption for an entire week, and the river rose with great rapidity to a height of 40 ft., bringing down immense quantities of drift-wood.

The trestles were, of course, carried out, and as there was not the slightest probability of the water falling, so as to admit of their being replaced before the following summer, all idea of completing the bridge in the ordinary manner had to be abandoned.‡ The following plan of erecting by the use of temporary trusses was then determined on. Between the pivot and end supporting pier on the west side, and at a distance from the latter of about 25 ft., there was left standing one of the old timber piers of the original bridge, and this being readily accessible from the fixed span by ordinary stringers, the opening which had to be spanned to reach the pivot pier was reduced to 95 ft. Two light timber trusses, of the Pratt system, 98 ft. in length, were then framed and erected on the river bank, and each one launched separately and floated into position between the pivot pier and timber pier just mentioned.

In the meantime the river had fallen considerably, so that the height from the surface of the water to the top of the piers was about 45 ft.; the trusses were raised from the water by means of tackles and gears and two stout gin poles, and secured in the position they were to occupy. The west half of the draw and the gallows frame were then erected without difficulty. On the east side, however, there was nothing that could be used as a support for the temporary trusses between the new piers, and the distance between them being 114 ft. in the clear, the trusses were about 20 ft. too short to reach across. To reduce the opening so as to admit of using the same trusses, a heavy timber platform, 20

* Transactions of American Society of Civil Engineers.

† It might be continued that during the season of low water there was no occasion for opening the draw, as the largest boats on the river could readily pass under the fixed spans without lowering their smoke stacks.

‡ It may be asked why the draw was not erected in its open position, at right angles to the line of the bridge. The reason for not doing so was, that no "protector" had been built, and as the nature of the river bed almost precluded the driving of piles, the cost of erecting trestle work capable of resisting the force of the current and the drift, during the rise of the river, would have been so great as to render this plan objectionable on account of the expense.

ft. in length, was thrown out from the pivot pier, the outer end being firmly supported by suspension rods from the top of the gallows frame. The timber trusses were then hung from the upper chords of the completed iron trusses of the west section, and moved forward over the pivot pier until one end projected some 20 ft. beyond the timber platform.

It was in this transfer of the trusses that the principal difficulty was encountered, and the want of wire rope and other suitable appliances for handling heavy weights was most seriously felt. The trusses when detached from each other were, of course, exceedingly limber, and great care was necessary in moving them to prevent injury by buckling.

A Manilla cable, 4 in. in diameter, was stretched from the top of the gallows frame to the top of the fixed span on the opposite side, and on this it was designed to suspend the trusses, one at a time, while moving them into their final position; the height of the cable above the top of the piers and its angle of inclination being such, that it was supposed that the trusses, when hung upon it, would move readily under the influence of gravity.

Unfortunately, however, the cable had been thoroughly wet by a heavy rain, and though the stretch was thought to be pretty well taken out by tackles, the effect of the soaking proved much more serious than was expected. As the weight of the truss came upon the cable it gradually stretched and sagged down some 70 ft, so that the truss, instead of being held above the level of the copings, was about 30 ft. below them.

The plan of transferring by cable having thus proved a failure, the gin poles and tackles were again resorted to, and by means of them the trusses were finally drawn up to their place, one end resting on the east end pier and the other on the timber platform above described. As soon as the timber trusses were connected by putting in the floor beams and laterals, the erection of the iron trusses of the east section of the draw was begun, and in two days —20 working hours—from that time the bridge was completed and the draw opened for the passage of boats.*

The expense of erecting in the manner described proved rather less than was anticipated. The materials for the temporary trusses cost about $200, and the entire work of raising the pivot span, including the framing, raising and transferring of the timber trusses, was accomplished by a force of 18 men in 24 working days, so that the entire cost of erection did not much exceed $1,300.

* During the erection of the east section of the draw, the river being so high that boats could not pass under the bridge, navigation at this point was pretty effectually closed, and in anticipation of this event, on complaint of the steamboat owners of Mobile, notice had been served by the United States authorities, forbidding any prosecution of the work that would prevent the free passage of boats. To avoid the annoyance of a number of suits at law, a compromise was effected between the contractors and the several steamboat companies, by which the former agreed to pay a fixed rate per day for every day that navigation should be obstructed. The claims for damages on this account, amounting to $3,000, were paid by the contractors on the completion of the bridge.

CONSIDERATIONS RELATING TO SAFETY IN MANUFACTURE AND IN STORAGE OF THE MORE IMPORTANT EXPLOSIVE AGENTS.*

The degree of safety with which explosive agents may be manufactured is an important question connected with their extensive application. The fact that the manufacture of gun-cotton as now carried on involves not the slightest risk of explosion up to the final stage, when the material has to be dried, distinguishes it from most other explosive agents. In gunpowder manufacture liability to explosion exists throughout all operations, from the point when the ingredients are mixed; and with regard to nitroglycerine and its preparations, it appears that, up to the present time, occasional severe accidents during manufacture have been inevitable; they probably arise chiefly from occasional neglect by the workmen of essential precautions in dealing with the explosive liquid, and it is difficult to see how they are to be effectually guarded against. The immunity enjoyed by gun-cotton is due to its being wet, and therefore absolutely uninflammable, throughout all stages, even after it has been compressed into cakes or disks. At this point it contains 15 per cent. of water, the expulsion of which by desicca-

* From the Minutes of the Proceedings of the Institution of Civil Engineers (English).

tion is unattended by any liability to explosion, or even to ignition, if simple precautions are adopted. For storing large quantities with absolute safety, it is convenient to preserve the compressed gun-cotton in the damp condition as it is delivered from the presses. It has been thus stored for long periods without the slightest detriment; and its non-inflammability in this condition is aptly illustrated by the fact, that the perforations required in some of the charges are produced by drilling the damp gun-cotton, the drill used revolving at the rate of about 600 revolutions per minute. The gun-cotton employed in some extensive experiments recently made on the South Coast had been stored damp for nearly nine months, and was dried partly in the open air, and partly in a hot-air chamber, when required for use. On that occasion 6 cwt. of the damp gun-cotton, packed in 24 strong wooden boxes, was stacked in a wooden shed, and surrounded by inflammable material. The building was then fired, and soon burned fiercely, which it continued to do for about half an hour, when the fire gradually subsided, and the building and its contents were entirely consumed. The gun-cotton must have burned slowly as the surfaces of the masses became sufficiently dry, as at no period of the experiment was any burst of flame, due to rapid ignition, perceptible.

The possibility of extensively employing an explosive compound or mixture as a substitute for gunpowder, without special risk of casualties, is most intimately connected with the question of its stability. Mixtures of saltpetre or chlorate of potash with oxidizable substances of stable character may be generally relied upon to equal gunpowder in their unalterable nature under all conditions of storage and use in different climates; deterioration in explosive power by the absorption of moisture is the only prejudicial result which generally attends long-continued keeping of such mixtures. There are a few instances, however, in which absorption of moisture may in time establish slight chemical action between the components of such mixtures, and thus become not only the cause of more serious deterioration, but also a source of danger, as chemical activity, once started in preparations of this kind, may gradually increase, being promoted by the heat developed, until it attains a violence resulting in the spontaneous ignition or explosion of the mass. Instances are on record of the spontaneous explosion from this cause, of damp mixtures containing chlorate of potash, which have long been known to be perfectly stable when dry. Substances of organic origin, the stability of which is uncertain, require application with much greater caution to the production of explosive mixtures, as it is possible that changes may occur spontaneously in such substances, or may be established by natural atmospheric fluctuations of temperature, which may eventually give rise to an action between these materials and the oxidizing agent with which they are mixed, resulting in ignition or explosion.

Although the stability of compounds which are themselves endowed with explosive properties may appear perfectly reliable when they are in a chemically pure condition, it is susceptible of being seriously affected by comparatively minute causes; hence, the most scrupulous care in the production and purification of such substances is imperatively necessary. In this respect they compare disadvantageously with gunpowder, as a want of care in its production, though it may lead to accident during manufacture, or to an inferiority of the product, will not affect the stability of the material.

Both nitroglycerine and gun-cotton, when prepared in small quantities and carefully purified, have been long known by chemists to be subject to very gradual chemical changes when exposed frequently to sunlight, and also to be liable to slow or rapid decomposition if exposed to temperatures considerably higher than occur as extremes under natural conditions in any climate. Both substances are also well known to have exhibited great stability under normal conditions of preservation, and even when continually exposed to light; but though many specimens exist which have remained unaltered almost since their first discovery a quarter of a century ago, the instances are numerous in which laboratory specimens have undergone spontaneous change with more or less rapidity.

The apparently variable nature of those substances is due to the retention by them, in some instances, of small quantities of impurities, comparatively unstable in their character, derived from foreign matters in the cotton or the glycerine; exposure to a high temperature or to sunlight may develop changes in them, resulting in the

production of acid matters, the development of which may lead to the establishment of chemical change in the nitroglycerine or gun-cotton; hence they may constitute the germs of decomposition. Such impurities would be, to some extent, enclosed in the hollow fibres of gun-cotton, and can then only be removed effectually by a breaking-up of the latter, and long-continued washing; in nitroglycerine they would be held dissolved by the substance, and their removal can also be only effectually accomplished by reducing the liquid to a very fine state of division, and submitting it to protracted washing, with the aid of alkaline agents.

For many years nitroglycerine was universally regarded as specially liable to spontaneous change. Even samples of different quantities of several pounds each, which, within the last four years, were produced at Woolwich in immediately successive operations, all apparently under the same conditions and with the special object in view of obtaining a thoroughly purified and stable material, have exhibited great differences in their keeping qualities. They have all been preserved in the dark, side by side; some are now in their originally pure condition, others have become more or less strongly acid, and two or three have undergone complete metamorphosis into oxalic acid and other products. The manufacturing and purifying processes, as perfected by Mr. Nobel, appear to furnish more reliably uniform products than those usually obtained on a small scale; and such specimens of these products as Mr. Nobel has had an opportunity of examining have exhibited great stability. Yet, if it were possible to trace accidental explosions to their cause more frequently than is the case, an exceptional want of stability might perhaps have been found, in some instances at any rate, auxiliary in bringing about the violent nitroglycerine explosions which have occurred. It has, however, been already established, by extensive experience during the last three years, that nitroglycerine is a far more reliable material than was formerly believed, and that if the most scrupulous attention is paid to the purification, and is combined with vigilance during storage and use, and the adoption of certain precautions which have already been proved important safeguards against chemical change in materials of this class, the risk of accident is so greatly reduced as to warrant the extensive manufacture and employment of nitroglycerine preparations under restrictions similar to such as may be deemed sufficient in the case of other explosive agents.

The extensive experiments and observations which were set on foot nine years ago by the Government Committee, and have been continued to this day, on the keeping qualities of gun-cotton prepared by the Austrian process, have furnished most satisfactory results. Considerable quantities of gun-cotton, in a great variety of forms, have been stored at Woolwich for several years, and their periodical examination has failed to afford any reason whatever for doubting the stability of gun-cotton under all conditions of storage which are likely to occur. The experience thus gained applies even more favorably to gun-cotton reduced to pulp, according to the system lately in use, whereby the uniform purification of the substance is more effectually secured. Compressed gun-cotton has not only been stored extensively in different parts of Great Britain, but it has also been exported in considerable quantities to Australia, the West Indies, India, South America, and other distant countries, and has been used under circumstances specially trying to any material of uncertain stability.

The explosions which occurred at Stowmarket, ten months ago, had the natural effect of dispelling from the public mind the great confidence which was becoming very generally entertained in the stability of gun-cotton. Fortunately, the facts which were elicited in the course of the inquiry constituted so complete a chain of evidence as to place the first cause of the explosion beyond any reasonable doubt, and to demonstrate that it was quite independent of any want of stability of the properly manufactured material. A supply of gun-cotton delivered from the works at Stowmarket, forming part of a quantity of which there remained a store in the magazines that exploded, was found to contain a proportion of disks in a highly impure condition. The amount of free (sulphuric) acid existing in some of these disks was so considerable that it could not possibly have been left in the gun-cotton after the first rough washing which it receives immediately on removal from the acid, and before conversion into pulp in the rag-engines, where it is beaten up for several hours with a large volume of water. Supposing,

therefore, that the gun-cotton-pulp composing these disks had been submitted to the compressing process without being passed through the intermediate and principal purifying operation, it could not possibly have contained even a small proportion of the sulphuric acid which was disovered in the impure disks; and the same would have been the case even if the unpulped gun-cotton, after the preliminary washing and wringing, could have been converted into compressed disks. It was indisputably established, therefore, that the sulphuric acid discovered in the impure gun-cotton, and which could not have been generated by any decomposition of the substance, must have found its way into the finished material in some manner totally unconnected with the process of manufacture, and that no amount of carelessness in manufacture, even to the extent of partial omission of the purifying processes, could have led to the existence of the acid found in the impure substance. That this impurity was sufficient to establish rapid change was sufficiently proved by the condition of some of the disks; and that this chemical change, accelerated as it was by the great heat of the weather at the time, gave rise to a development and accumulation of heat inevitably culminating in the ignition of some portion of the stored gun-cotton, was readily demonstrated by simple experiments with some of the impure disks themselves. But although the ignition of the store of gun-cotton in the lightly-built magazines at Stowmarket was completely accounted for, the very violent character of the explosions, and especially that of the second explosion of a small store which was burning for a considerable time before its contents detonated, were results quite unexpected to those well acquainted with the properties of gun-cotton in the compressed form.

Many practical experiments had demonstrated that it might be submitted to extremely rough treatment without any risk of its explosion; and single packages of the closely-confined material had been repeatedly ignited, from within and without; no other result than an inflammation and a rapid burning of the gun-cotton having ever occurred. These demonstrations of the apparent immunity from explosive properties of compressed gun-cotton, unless strongly confined or fired by detonation, appeared to be fully confirmed by the results of a somewhat extensive experiments made at Woolwich a year ago, with gun-cotton packed in firmly-closed strong wooden boxes of the kind which Government proposed to use for storing the material. Eight such packages, each containing 28 lbs. of gun-cotton, were enclosed in a pile of similar boxes loaded to the same weight, and the contents of the centre box were ignited. No explosion resulted, and the contents of some of the boxes even escaped ignition. A second experiment, in which the centre box was surrounded by inflammable matter, so that a fierce fire burned within the heap for many minutes before the gun-cotton ignited, was also unattended by any approach to an explosion. The apparently conclusive nature of these experiments undoubtedly encouraged a false confidence in the non-liability to explosion of stores of gun-cotton in the event of accidental ignition; and the catastrophe at Stowmarket demonstrated the imperative necessity for a more extensive investigation of the subject.

The results of some experiments recently instituted near Hastings, by the Government Committee on gun-cotton, have already served to throw great light upon the manner in which the explosions at Stowmarket were brought about. In the first instance, twenty-four boxes (containing 6 cwt. of gun cotton), of the kind used in the Woolwich experiments, were stored upon tables in a small wooden shed of light structure, and a heap of shavings and light wood was kindled immediately beneath the boxes, two of which were left partly open. After the fire had been burning for about seven minutes the gun-cotton inflamed, and continued to burn with rapidly increasing violence for nine seconds, when a sharp explosion occurred. A very similar result was furnished by a second experiment, in which the same number of boxes of gun-cotton were stored in a small magazine of stout brickwork. By subsequent comparative experiments it was judged that a considerable proportion of the gun-cotton had burned in both instances before the explosion occurred; but these were nevertheless of such violence as to produce large craters in the shingle on the site of the buildings, and to project the debris with much force to considerable distances. Two repetitions were afterwards made of the first experiment, in wooden sheds of similar structure, with correspond-

ing quantities of gun-cotton, similarly arranged in boxes of the same size, and fastened down, just as securely as those in the former experiment; but the boxes were made of somewhat thinner wood, and were constructed less strongly. In neither of these experiments did an explosion occur. In the one instance the fire was burning in the building for more than half an hour before the gun-cotton became ignited, and, three minutes after the first great blaze had subsided, there was a second blaze of gun-cotton. Although the latter must have been exposed to intense heat, no explosion was produced. In the second experiment, the gun-cotton burned in three successive portions, the last having been exposed for many minutes to a fierce heat, yet burning non-explosively.

The first two of these experiments demonstrated that if, in a store containing packages of gun-cotton in somewhat considerable number, the material became accidentally inflamed, the intense heat developed by the burning material in the first instance might raise some portion, still confined in boxes, to the inflaming point, and that then, the mass of the confined gun-cotton being in a heated condition, the ignition would proceed with such rapidity as to develop the pressure essential to explosion while the gun-cotton was still confined, the resulting explosion being instantaneously transmitted to other boxes. When the magazines at Stowmarket exploded, a large volume of flame was observed to precede the explosion by a distinct interval. The two other experiments described appear to demonstrate that with such quantities as were stored in the experimental sheds, the fact of the material being confined in boxes of comparatively light structure constitutes a safeguard against explosion, the reason being that the weaker packages are opened up by comparatively feeble pressure from within; hence, when the contents of a box become raised to the inflaming temperature, or become ignited by the penetration of flame to the interior, the pressure developed by the first ignition is not sustained by the box to a sufficient extent, or for a sufficient time, to bring about explosion.

On the occasion of the Stowmarket accident there were two store sheds, containing gun-cotton packed in boxes of light construction, which were ignited by the first explosion, and burned out without exploding; while a third, which contained gun-cotton packed in the strong Government boxes, exploded with great violence, after having been in flames for some time.

Simple experiments serve to demonstrate that if any explosive compound or mixture be ignited when in a heated condition, it will burn with a violence proportionate to the temperature to which it has been raised. If this be near the exploding point, the result must be an explosion which will be violent in proportion to the degree of confinement of the material. A practical demonstration of this was furnished by an explosion which occurred at Woolwich in 1866. Several strong packages (metal-lined cases), filled with von Lenk's gun-cotton, some of which was purposely left impure, had been exposed for seven months to artificial heat in a strong brickwork chamber heated by steam. The impure gun-cotton in some of the packages was then known to be in a decomposing state, but the experiment was continued, and eventually spontaneous ignition occurred at a time when the boxes were heated to the maximum temperature. The result was a violent explosion of all the packages; the very strong confinement, and the heated condition of the gun-cotton which ignited, added to its being at the time in a state of chemical activity, determined its explosion, and the explosion of the other packages was a necessary consequence of the violent concussion to which they were exposed.

There can be no doubt that the results of the recent experiments and of those made last year, as also the results of the Stowmarket accident, have to be considered in relation to the quantities of gun-cotton operated upon, as well as to its confinement. The confinement of the eight strong packages by the layers of boxes which surrounded them on all sides, in the Woolwich experiment, was probably quite as great as that afforded by the light and roomy shed in which twenty-four boxes of the same kind were placed in double layers, in the South Coast experiment; yet in the latter case an explosion was developed, and not in the former with the smaller quantity. In the South Coast experiments, with 6 cwt. of gun-cotton, the explosions occurred 8 sec. and 10 sec. after the ignition of the gun-cotton; in the Stowmarket magazine, where several tons of gun-cotton were stored, the explosion appears to have almost immediately followed ignition; it must be borne in mind, however, that in this

case much of the gun-cotton was closely confined by the large number of surrounding packages, and that the temperature of the gun-cotton was already raised considerably throughout by long continued hot weather. Both of these circumstances must have greatly favored the rapid development of explosion, independently of the much more intense heat generated by the rapid spreading of fire through a large proportion of the gun-cotton. The satisfactory results obtained in the South Coast experiments with the lightly-constructed boxes, with employment of 6 cwt. of material, appear to have received confirmation from the result of an accident which occurred in 1869 at Penryn, when a magazine of brickwork containing 20 cwt. of compressed gun-cotton, packed in boxes of light structure, was burned down without any explosion. But it is, nevertheless, very possible that a similar result would not be furnished by several tons of gun-cotton similarly packed; the much higher temperature which would be developed in that case by the first spreading of the fire, and the additional confinement, due to the larger number of packages, might combine to develop conditions favorable to the violent explosion of some portion of the mass, though no doubt a much larger proportion would burn non-explosively than if strong boxes were used. While, therefore, in strong dry gun-cotton, the probability that violent explosions will result from the accidental ignition of a magazine may be considerably diminished, or, at any rate, the violence of a possible explosion may be much reduced, by storing the material in packages of which some portions will yield readily to pressure from within, or by adopting any other storage arrangements whereby the rapid penetration of flame or heat between the compressed masses is promoted, it must be considered as conclusively established by the last twelve months' experience, that such regulations as experience and prudence have rendered essential in connection with the storage of gunpowder and other explosive agents, must also apply to the storage of compressed gun-cotton when in the dry state.

FAIRLIE ENGINE FOR THE MEXICAN RAILWAY.

From "Engineering."

The practical development of the Fairlie system of locomotive has just been advanced one step further by the completion of another engine for the Mexican Railway. This is the fifteenth which has been built for that line, upon which the system was originally introduced some two years since by Mr. G. B. Crawley, whose firm are the contractors for the Mexican Railway. In taking the step he then did, Mr. Crawley encountered strong opposition, which, however, he finally overcame. The results of working bear ample testimony to the soundness of his judgment, inasmuch as a saving of 50 per cent. in cost of maintenance of the road is reported to have been effected on that portion of the line worked by the Fairlie locomotives. The engine to which the present notice refers was built by the Yorkshire Engine Company, and with it some interesting and conclusive trials were made yesterday week. The experiments were undertaken at the request of the Directors of the Mexican Railway, and by the courtesy of Mr. Charles Sacré, the locomotive superintendent of the Manchester, Sheffield, and Lincolnshire Railway, they were carried out on the Dropping Well Incline of the South Yorkshire Railway. A number of engineers and other gentlemen directly interested in railways, attended the trials, and among them were Mr. G. B. Crawley, Mr. S. W. Johnson, locomotive superintendent of the Midland Railway, Mr. W. Roebuck, Messrs. Ramos Brothers, of the Lima and Pisco Railway, Mr. W. J. Hammond, of the San Paulo Railway, Brazil, Mr. James Young, of the East Indian Railway, Mr. Harry Stanger, representing the Crown agents for the colonies, Mr. Robert May, Mr. Alexander, formerly of the Mont Cenis Railway, Captain Hobson, etc. Mr. Fairlie is at the present time engaged on professional matters in South America in connection with the narrow-gauge railways there constructed, and working on the Fairlie system, as well as others in course of construction. He was, however, represented at the trial by Mr. Royce, his manager. The experiments were arranged, and personally superintended, by Mr. E. Sacré, the managing

director of the Yorkshire Engine Company.

The engine in question, which has been named the "Hildalgo," is of the double-bogie type, and is very similar in construction to one for the Iquique Railway, which will be found described and illustrated in our issue for Nov. 14, 1873. A few leading particulars will, therefore, be all that is necessary upon the present occasion. The engine has four 16 in. cylinders, with 20 in. stroke, a collective heating surface of 1,729 sq. ft., and a grate area of 29 sq. ft. The capacity of her water tanks is 2,000 gallons, whilst her bunkers will contain 30 cwt. of coal, and her crates 400 cubic ft. of wood fuel. She is carried on twelve wheels, 3 ft. 6 in. diameter, all coupled, and her weight in working order is 62 tons. All the wheels being coupled, the whole of her weight is available for adhesion. With a mean cylinder pressure of 90 lbs., the tractive force at the rails is 21,940 lbs., and 24,200 lbs., with 100 lbs. mean pressure. Like those which have preceded her on the Mexican Railway, she has been designed for working the 4 per cent. gradients (1 in 25) on that line. In view of this, she has been fitted with a Chatelier steam brake, besides which she carries a Westinghouse air brake. Another noteworthy feature in this engine is the arrangement of the boiler tubes, the upper rows of which are inclined downwards from the firebox to the smokeboxes, the result being that even when the engine is on the steepest gradient the tubes are always well covered with water. The top of the boiler being raised high over the firebox, a large steam space is formed, from which the steam is taken perfectly dry, no matter at what angle the water may be standing in the boiler.

The branch line on which this engine was tried is known as the Dropping Well Incline of the South Yorkshire system. This is a single line of 2¼ miles long, 1,880 yards of this length being on a gradient of 1 in 50, while the ruling gradient, which is about a quarter of a mile in length, is 1 in 32. Curves of 7 chains radius occur on the line, two of them being **S** curves, and one of these latter being situated on the ruling gradient. At the summit are situated the Grange Collieries, which in fact the line serves, the junction with the main line being near the Grange-lane Station. The train with which the first run was made consisted of the engine, which weighed 62 tons, twenty loaded coal wagons weighing 275 tons, a composite carriage, two goods brake vans, and two luggage vans weighing 48 tons, and fifty passengers, whose weight may be taken at 3 tons, the gross load moved being therefore 388 tons. At 11.30 A. M. the "Hildalgo" started at the foot of the incline and on the gradient of 1 in 32 for 1¼ mile to push this train before it up to the collieries, the pressure gauge recording 112 lbs. The reason why the train was pushed was in order to guard against the possible contingency of a coupling giving way, which with the engine hauling, would have allowed the detached wagons to have run back on to the main line, and thus perhaps to have added another to the long list of recent railway accidents. Owing to a frost which had covered the rails with rime, and which was followed by a warm sunshine, but which had partially thawed just before the trial, and to the comparatively low steam pressure with which the engine had started, the progress of the train was but slow. The "Hildalgo" slipped considerably, until at length she came to a stand on a gradient of 1 in 32, and a curve of 7 chains radius. This took place 12½ min. from the time of starting, and the pressure gauge showing 110 lbs. In 7½ min. more she was blowing off at 140 lbs., and she then made a fresh start, stopping for 1 min. by signal when near the collieries, and reaching the top of the bank in 28 min. from the time of starting, including stoppages, and showing 135 lbs steam. A few minutes later the train was dropped down the incline to the junction, both the Westinghouse and Chatelier brakes being used to retard the impetus of the moving load of nearly 400 tons.

The train was then run back to the Yorkshire Engine Company's Works at Meadow-lane, where two loaded wagons were detached, reducing the gross load to 365 tons, including the engine. With this reduced load the second run was commenced from the same starting-point as previously, the engine pushing the train before it. A fair start was made with the gauge at 140 lbs., which had fallen to 115 lbs. when the train had reached the top of the grade of 1 in 32 and entered upon that of 1 in 32, a mile and a quarter up the incline. In 9½ min. from the time of starting the train had reached the top of the bank with 110 lbs. steam, after having made a very steady run at the rate of 14.2 miles

per hour. The only incident of note on the ascent was a slight slipping of the rear bogie when the engine entered upon the grade of 1 in 32. The train was then dropped down the incline on to the main line, and was run thence back to the Yorkshire Engine Works, having performed her allotted task in a manner as satisfactory as it was convincing to all present. In fact, no better proof could have been desired of the capability of the Fairlie system. The engine was driven by Mr. J. Sharpe, of the Manchester, Sheffield, and Lincolnshire Railway, and her capacity for work is best shown by comparing the results of the trials with the usual practice on the Grange Colliery branch. There the ordinary load for a six-wheeled coupled goods engine is 97 tons, the weight of the engine and tender being 48 tons. It will thus be seen that the results attained by the "Hildalgo" are very successful, and are rendered all the more remarkable from the circumstance that she had to push a long train up steep inclines and against exceptionally sharp curves, the most trying conditions that could be imposed. The experiments satisfactorily prove the advantages which the system possesses for working the present heavy mineral traffic on many main lines. The number of trains would be reduced by about one-half, the chances of accidents being diminished in the same proportion.

On alighting from the train at the Meadow Hall station, the visitors proceeded to inspect the works of the Yorkshire Engine Company, over which they were conducted by Mr. Edward Sacré There they found amongst other machinery in hand a number of Fairlie locomotives in various stages of progress for foreign railways.

REPORTS OF ENGINEERS' SOCIETIES.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—*January 21st*, 1874.—A stated meeting was held at 8 o'clock P. M. The subject for consideration, "Tests of Materials used in Construction and Testing Machines," was announced. Communications, and the following papers in response to the circular sent out, inviting discussion, were presented: "Experiments on the Tensile Strength of Bar Iron and Boiler Plate," by Charles B. Richards, M. E.; "Proportions of the Heads of Eye Bars," by Charles Macdonald, C. E.; "Tests of Wrought-Iron Beams and Rods," by T. Guilford Smith, C. E.; "Tests of Bridge Irons," by Gen. W. Sooy Smith; "Effects of Cold on Iron and Steel Rails," by A. D. Briggs, Esq., and "Experiments on Steel Wire," by Thomas C. Clarke, C. E.

The papers, "Experiments on the Tensile Strength of Bar Iron and Boiler Plate," "Proportions of the Heads of Eye Bars," and "Tests of Bridge Irons," were read and discussed.

Descriptions of the hydraulic weighing apparatus of Mr. Albert H. Emery, and of various testing machines in use, were given, after which, inquiry was made into what should be sought for in testing materials.

February 4th, 1874. A communication from Hon. William J. McAlpine, affirming the propriety of engineers making charge, the same as other professional men, for advice given, and one from Prof. Estevan A. Fuertes, asking the Society to declare what should be the course of instruction in schools and colleges, for students of engineering, were read. The latter was referred for consideration and report to a committee, consisting of Prof. De Volson Wood, Mr. Charles Macdonald and Prof. George W. Plympton.

Prof. Robert H. Thurston read a paper entitled "Researches on the Resistance and the Physical Properties of Materials," illustrated by his machine for making graphic tests of the torsional strength of materials; which, with its manner of working, was exhibited, and samples of tests made were shown. Consideration of this paper was deferred to the regular meeting to be held on April 4th, and by vote Prof. Thurston was thanked for the clear, novel and able presentation of the subject made.

AMERICAN INSTITUTE OF MINING ENGINEERS. —MEETING OF THE MINING ENGINEERS.—The first meeting of the tenth session occurred on Tuesday evening, February 24th, at the rooms of the Geographical Society, in Cooper Institute, New York. Only a small fraction of the whole number of members were present, probably not more than 25 or 30 being at the meeting, but among these were gentlemen from the Eastern, Western, Northern, and Southern States. Rossiter W. Raymond, the President, occupied the chair. The meeting was opened with an address by President J. A. P. Barnard, of Columbia College.

On Wednesday they made their excursion to the Ringwood and Sterling mines, in Passaic County, N. J.

At 10 o'clock, Thursday, the Association again met in the Cooper Institute. The following papers were read: "The Bruckner Revolving Roasting Furnace," by J. N. Locke; "A Direct Process for the Production of Iron," by Thomas S. Blair, of Pittsburg; "Exploration by Means of the Diamond Drill," by Oswald J. Heinrich, of Midlothian, West Va. It being two o'clock when the last paper was read, the meeting was adjourned for an hour.

Mr. Heinrich's paper was discussed at the reassembling of the Convention at 3 o'clock, after which Eckley B. Coxe, of Drifton, Penn., made some remarks on "Improvements in Measuring in Mine Surveying:" Edmund C. Pechin, of Dunbar, Penn., followed Mr. Coxe with a short paper on "An Explosion at Dunbar Furnace." The last paper of the afternoon session was on "The Coal Deposits of Hocking Valley, Ohio," by Dr. T. Sterry Hunt, of Boston. It was 5 o'clock when

the discussion of Dr. Hunt's paper was concluded, and an adjournment was then had to 8 P. M.

The whole of the evening session was devoted to the reading and discussion of two long papers—one by Prof. John C. Smock, of New Brunswick, N. J., on "The Magnetic Iron Ore of New Jersey," and the other by J. M. Adams, on "The Crushing and Treating of Gold and Silver Ores."

The members resumed their session on Friday morning. A paper which was begun on the previous evening, on "The Crushing and Amalgamation of Ores," was read by J. M. Adams, of Silver City, Idaho.

In the absence of Dr. Thomas M. Drown, his paper on "The Determination of Sulphur in Pig Iron and Lead" was read by the Chairman. In it were described various methods of determining the amount of sulphur in each of these two metals. One method was by mixing borings of the metal with muriatic acid and passing the gaseous vapor through a solution of lead or silver, which precipitates the sulphur; it could also be precipitated by using, instead of silver or lead, a solution of the permanganate of potash. A paper which had been prepared by J. F. Blandy, who was absent, on the "Stamp Mills of Lake Superior," was also read by the Chairman. It was then resolved that the next meeting of the Society should be held in May, in St. Louis.—*Abstract from N. Y. Tribune's Report.*

IRON AND STEEL NOTES.

ALLOY OF IRON AND MANGANESE.—If one mixes small pellets, filings, or turnings of wrought iron, of cast iron, or of steel, or any other scraps of cast iron, wrought iron, or steel, with minerals containing manganese, tungsten, or titanium, or many of these metals mixed, or with quartz; these minerals or quartz finely powdered, and introduced in suitable proportions for the required alloy; if this mixture be watered completely and regularly throughout with an ammoniacal solution, or a slightly acid solution; if this compound, says the "Chronique de l'Industrie," compressed by hand or mechanically, be shut up in an iron mould, it produces a great development of heat, and at the end of some hours, on opening the mould, a compact mass is found, very hard, that can be broken in a mortar into fragments of any required size. These fragments are perfectly stable up to a red heat, and only disengage at the point of fusion of cast iron. Their treatment in a suitable furnace gives alloys containing iron and manganese in all proportions, from 25 per cent. to 50 per cent. of this latter metal, of silicates of iron containing up to 22 per cent. of silica, and also of alloys of iron and tungsten or titanium, or again triple alloys of these different metals. But these results cannot be obtained but at very high temperatures, that is to say, it is necessary to construct apparatus in which one can use a blast of a very high temperature and pressure.

Under these conditions, and in presence of energetic bases, the furnace is rapidly attacked, principally in the lower parts. It is, therefore, necessary to construct it in the following manner: The furnace is composed of a chamber of refractory bricks, as hard as possible, in which alumina predominates, of a material composed of lime, of manganese, or of pure alumina, and of a hearth composed of carbon, lime and manganese. The blast is heated at least to 35 deg. C., and its pressure ranges to about 13 to 15 centimetres of mercury.

Apropos to this new alloy which the Terre-Noire Company are manufacturing, it will not be, perhaps, without interest to recount the essays tried in this direction to obtain certain qualities of iron that are actually sought, and which, it appears, should be produced under these conditions. The ferro-manganese has been produced, up till now, by two methods—the first is due to Prieger, and is made in crucibles; the second is due to Henderson, and is made in a regenerative furnace. These two methods are founded on simultaneous reduction, in the presence of finely-divided carbon, of a mixture of minerals of iron and of manganese, powdered. The presence of iron in the mixture determines the complete reduction of the oxide of manganese, and it is indispensable for this reduction.

One knows how difficult it is to obtain metallic manganese in laboratory researches, and how a complete reduction of an oxide of manganese by carbon alone requires time and fuel, on account of the pulverulent condition of the mixture, and of the poverty of the flux, which ought to contain an excess of carbon. These two methods can only give but small quantities of alloy daily, and at the cost of an enormous consumption of fuel. There is room, then, to seek a more practicable method from these two points of view, acting in a continuous manner, producing a more complete and simultaneous reduction of the oxides, and their following fusion. With this view, there has been constructed a vertical apparatus similar to a cupola furnace, and into it are introduced the minerals of iron and manganese. Castings have been produced containing, in these circumstances, as much as 18 per cent. of manganese; only it appeared that the special minerals for this product are so rare that the manufacture could not be continued(?). Other essays have been made in this direction in the form of bricks, of amalgamations, etc., but nothing has succeded in this way. Now, one of these special alloys is assuredly much used in England; it contains, according to the analyses, 30 per cent. of manganese, 5 per cent. of iron, and 5 of carbon. Now, it is with the object of arriving at such a production, that the company of Terre-Noire has undertaken its essays, and pretends to have succeeded.

RAILWAY NOTES.

SPEED ON NARROW GAUGE.—One great objection has been made to the 3-ft. gauge roads, that passenger trains must be run at a very slow rate. This objection is daily answered by the Cairo & St. Louis Narrow Gauge Road, 90 miles of which have been in operation for some time. Their passenger trains run this distance in 4 hours 50 min., and make 16 stops. Their schedule time is over 18.6 miles per hour over maximum grades of 94 ft. to the mile, and their regular train is four cars, weighing in the aggregate, with passengers, 52 tons. This is about the average rate of mail trains on wide-gauge roads with much easier grades. The engines were built at the Light Locomotive Works of Porter, Bell & Co., Pittsburg, Pa., and have 10x16 in. cylinders and

44-in. drivers. On a special trial one of the three engines hauled its train 9 miles in 10 min., or at the rate of 54 miles per hour. Several prominent Chicago railway officials were on the train, two of them riding with the engineer when this "spurt" was made. They pronounced the motion quite as easy as on any broad-gauge road.—*Chicago Railway Review.*

ENGINEERING STRUCTURES.

THE LARGEST TUNNELS OF THE WORLD.—The completion of the Hoosac tunnel and the rapid progress of the Sutro, have caused the miners, both in the East and in the West of America, to look with interest upon what has been and is projected in connection with tunnel driving. It is in Germany that the great tunnels have been constructed, and these have been made exclusively for mining. There is the great tunnel at Freiberg, 24 miles long; the Ernst-August and the Georg at Clausthal, 13½ and 10¾ miles respectively; the Joseph II. at Schemnitz, 9½ miles; the Rothschonberg at Freiberg, 8 miles; the Mont Cenis, 7½ miles, which about completes the European list. In the United States we have the Hoosac, in Massachusetts, 5 miles long, the completion of which has lately been noticed; the Sutro, in Nevada, for opening up the celebrated Comstock lode. This tunnel, although only 4 miles long, will, with its ramifications to the various mines of the district, prove one of the most important in America. The Sierra Madre tunnel at Black Hawk, commenced during the present year, and which will be 12 miles long, as well as the San Carlos and Union Pacific tunnels, which are under 2½ miles. The Ernst-August tunnel was driven at the rate of a mile per annum, and it will be interesting to notice how long it will take the Americans, with all the approved appliances at present at command, to complete the nearly similar Sierra Madre tunnel.

THE DETROIT BRIDGE.—The report of the commissioners appointed by the Secretary of War to inquire into the feasibility of bridging the Detroit River has been laid before Congess. The commissioners have given a hearing to all parties interested and have collected statistics bearing on the question. They are inclined to think the water traffic much more important than the railroad traffic which crosses the river, and believe that a tunnel is the only unobjectionable method of overcoming the obstruction to railroad traffic. This tunnel they believe to be practicable. No bridge giving passage to vessels by draws alone, with any draw-span now possible, can be built without serious obstruction to navigation. A bridge giving a clear headway of 150 ft. and clear spans of 400 ft. would not seriously obstruct navigation, but would be very expensive and the approaches would be long, and very inconvenient to construct. A third plan considered was a bridge for winter use only, resting on pontoons in the centre of the river and piers at the sides, which could be removed so as to leave a clear opening of 700 ft. during the season of navigation. This, the Commission believes, could be built without serious hinderance to navigation and at a reasonable cost, but it would only be of use some five months of the year.

ORDNANCE AND NAVAL.

A DESTRUCTIVE ENGINE OF WAR.—The recent trial of the Taylor battery gun, upon which the Colt Company, of Hartford, has for some months past been engaged, shows it to be the most formidable weapon of war that has yet been invented. Its barrels are twenty-four in number, and are arranged in two concentric circles. They are also regulated so as to radiate their fire, covering a horizontal line of 22 ft. at a distance of 500 yards. The gun fires with great rapidity, by fusilade or by volley, at the pleasure of the operator, while the cartridges are fed into the barrel from suitable charging cases, which are introduced into the interior of the breech cylinders. The results at the late trial were astonishing. In firing a single barrel at a distance of 500 yards, bullets were repeatedly sent into an 8-in. bull's-eye. In firing the fusilade, the 24 balls were distributed on a horizontal surface 22 ft. long at a distance of a foot apart; and firing by the battery the same results were accomplished. The rapidity of the fire was remarkable, being at the rate of 700 balls per minute. The terrible effectiveness of this weapon in battle, and the utter powerlessness of charging columns in the face of a fire, can be seen by the fact that every second sweeps over 20 ft. in length, and mows down men at the rate of a regiment a minute. The inventor of this remarkable weapon is Colonel James P. Taylor, of Knoxville, Tenn. His invention was conceived in 1870, and patented in July, 1871, and it has since been improved until its present extreme simplicity and effectiveness have been reached. The manufacture of the gun is to be rapidly pushed, and active measures taken for its introduction among foreign governments.—*Iron World.*

IRON STEAMERS FOR SOUTH AMERICA.—Two iron steamers have been completed at Messrs. Hartupee & Co.'s foundry in Pittsburg for service in South American waters. The vessels were built for the Rio Janeiro Steamship Navigation Company, and will be shipped in sections and put together on their arrival at Buenos Ayres. The smaller boat, with her machinery complete, only weighs 13,000 lbs., and is 90 ft. long, while the larger is 120 ft. in length, 26 ft. beam, and 4½ ft. hold. Messrs. Hartupee & Co. will probably soon receive another and a larger contract from the company, a correspondence relative thereto having taken place. These vessels after being put together are taken apart and packed in boxes, every piece being numbered. No less than 1,200 boxes are required.

THE Committee on Explosives at the Royal Arsenal, Woolwich, are about to make some experiments with an 18-ton gun, for the purpose of testing the advantages to be gained by various lengths of bore. The gun prepared for these experiments has a rather eventful history. It was first of all fired as a 10-in. gun, re-rifled, and drilled through and through in various parts for the insertion of pressure gauges to ascertain the force of the explosion, and the gun in this state sustained some very heavy strains. It was afterwards rifled, and again underwent some extraordinary pressures, and it was subsequently bored up to 11 in., firing a number of rounds with heavy charges,

until at length the tube cracked while firing 1,200 lbs. shot with 85 lbs. of powder. A new tube has since been put in, and a considerable piece added to the muzzle, so that the gun is at the present a little over 20 ft. long, with a bore of 11 in. still. The most advantageous length for land service guns will, no doubt, be ascertained by experiments with this piece of ordnance. Naval guns are of necessity short. The advantage of length of bore is that slower burning, and consequently less dangerous powder can be used, as the guns have a longer space in which to act upon the shot, which thus acquires its velocity at less expense to the gun. The gun above described has been fully prepared at the Royal Gun Factories in the Royal Arsenal, Woolwich, for these experiments.

BOOK NOTICES.

A PRACTICAL MANUAL OF CHEMICAL ANALYSIS AND ASSAYING, as applied to the Manufacture of Iron from its Ores, and to Cast Iron, Wrought Iron and Steel, as Found in Commerce. By L. L. DE KONINCK, DR. SC., and E. DIETZ, Engineers. Edited with notes by ROBERT MALLET, F. R. S. London: Chapman and Hall. For sale by D. Van Nostrand.

If it is true that no complicated manufacture of modern times can be successfully carried on and improved without the continual aid of science, then we shall be prepared to expect that in localities in which any such manufacture is extensively and successfully followed, the sciences related to it will be thoroughly investigated in theory and reduced to form as practical arts. This is particularly the case with the manufacture of iron and steel; and no one who has personally observed the perfection and the proportions of this business in Belgium, will be surprised to find that it is accompanied in that country with a valuable technical literature. The authors of the manual before us, being both skilful and learned in the metallurgy of iron, have undertaken to present, in a concise form, the information most frequently required by chemists in iron works, for whom this book is specially intended. But, as the editor justly remarks, it is a work, from the careful study of which, accompanied by the self-instruction derivable from a repetitive course of the operations described, any tolerably intelligent man, with some preliminary knowledge of organic chemistry and manipulation, might become a practical iron assayer. It is, therefore, particularly well adapted to be useful to American iron masters, many of whom already possess, and all of whom may easily obtain, the prerequisite general acquaintance with chemical principles and processes.

The plan of this manual will appear from a brief recital of its contents. The first part contains a description of the reagents to be employed, and the experiments necessary in order to ascertain their degree of purity; in the second part are given some practical suggestions relative to the apparatus employed in the laboratories attached to ironworks; the third part treats of volumetric assaying; the fourth is devoted to the analysis of iron ores, slags, and scoriæ, by the wet method; the fifth part treats of the assay of the same ores by the dry or docimastic method proper; the sixth gives the methods of analysis of malleable iron, cast iron, and steel; and the examination of fuels forms the seventh and last part. Since zinc and lead ores are occasionally found more or less in company with ores of iron, so as to complicate the analysis of the latter, the treatise is completed by a brief indication of methods generally used in analyzing them.

We have examined with interest the different sections of the book, with the view of ascertaining how clearly, and with how much detail, the processes involved are described, and to what extent the latest improvements in laboratory practice are included. In both respects we are able to commend the book heartily. Yet, excellent as was the treatment bestowed upon it by its authors, the admirable notes added by Mr. Mallet have, in our opinion, greatly augmented its practical value. They refer mainly to topics connected with actual practice in the laboratory, and contain a great number of useful suggestions, such as an accomplished teacher might drop for the benefit of his pupils in the familiarity of daily association.

The employment, in this manual, of modern chemical formulæ and atomic weights may prove at first somewhat inconvenient to those who have been brought up under the old-fashioned nomenclature; but, after all, there is no doubt that the new theories and arrangements of symbols will ultimately replace the old, and whoever intends to keep pace with the progress of technical literature must make up his mind, whether he likes it or not, to master its language. From this point of view, it is a great advantage to possess a text-book, by the aid of which modern treatises can be interpreted.

We notice that in the account of the colorimetric method of determing combined carbon in cast iron or steel, the very convenient apparatus devised by Mr. Britton is not described. This apparatus is specially adapted for use in large establishments, when frequent assays are required.

At the end of the book are several tables, giving the chemical equivalents, stoichiometric coefficients, and comparative weights and measures. The latter table enables a student to turn metric weights into British grains, but unfortunately does not facilitate the reverse calculation.—*Engineering and Mining Journal.*

NAVAL ARCHITECTURE: AN ELEMENTARY TREATISE ON LAYING-OFF WOOD AND IRON SHIPS. By J. S. P. THEARLE. London and Glasgow: W. Collins, Sons, & Co.

This little book, which seems to be one of a series of elementary science manuals in course of publication by the Messrs. Collins, had its origin in the desire of its author to supply a want he himself felt when a student. The book itself is a small 8vo, but it is accompanied by what is called vol. ii., a quarto containing the plates illustrative of the text. Mr. Thearle, who is in the department of the Comptroller of the Navy, is thoroughly competent to write a work of this kind, and we do not doubt that it will be of considerable importance to the student of naval architecture, containing, as it does, an explanation of nearly all the problems of common occurrence on the floor of the mould-loft. The technical terms used in this art of "laying-off" vary to such an extent in the different shipbuilding yards of the country, that

Mr. Thearle wisely adopts many terms used in descriptive geometry, thus obtaining a uniform nomenclature which will not be liable to be misconstrued by students in various parts of the kingdom. The text is divided into two parts, treating respectively of wood and iron vessels, and these again into chapters. After a brief introduction and an explanation of terms, Mr. Thearle plunges at once into the mysteries of the mould-loft and into technical details, which are, of course, of interest only to the student of the subject. About 120 pp. of text, and nearly fifty lithographic diagrams, enable the author to convey a thoroughly practical idea of the art.

OUTLINES OF GEOMETRY, OR THE MOTION OF A POINT. An Introduction and Companion to Euclid's Elements. By W. MARSHAM ADAMS, B. A. Third revised edition. London: Mead & Co.

Instead of seeking a substitute for a first book which has held its own as an introduction to geometry for some 3,000 years, a search apparently futile, Mr. Adams proposes in this work to provide the student, not with a substitute, but with an introduction to prepare him for the elements rather than to adapt the elements to him, and this by "presenting each geometrical conception in the concrete before it is presented in the abstract, so that the image in the mind precedes the definition." Evidently well acquainted with the *idola* which occupy the mind of the geometrical tyro, Mr. Adams, with much tact, dislodges these, substituting the accurate conceptions of exact science; in fact, communicates the same kind of preliminary information which might be given orally by a judicious teacher; and for this reason his little work must be invaluable as a help to those applying themselves to geometry without the aid of a master, or as a hand-book to inexperienced teachers of youth. Two sheets of diagrams, in some of which color is utilized, amply illustrate the letter-press.

HYDRAULICS OF GREAT RIVERS. THE PARANA, THE URUGUAY, AND THE LA PLATA ESTUARY. By J. J. REVY. For sale by D. Van Nostrand. Price $17.00, cloth.

The author of this work was appointed, three years ago, by the Argentine Republic, to survey their great rivers, and, as the magnitude of the subjects of the survey was so much in advance of the sources of the data hitherto employed in hydraulics, he took especial pains to insure a degree of accuracy not usually required for ordinary purposes. Acting on this determination, he made his observations, an analysis of which, we now find, gives results at variance with some of the principles accepted by hydraulic engineers. Mr. Révy has contented himself with giving an account of his survey and of its results; he does not attack the theories of others, nor state one of his own. The book is illustrated with excellent diagrams, and contains, amongst other things, a description with illustrations of a new current meter. The subject is one of special interest to hydraulic engineers and to Boards of Works, and dealing, as it does, with the preservation of rivers as channels of communication, it is of imperial importance. Mr. Révy writes in an agreeable style for such a subject, and many of his pages contain information upon the geology of the districts, while here and there is an account of an adventure—the rivers being at the time, it will be remembered, the "seat of war."

TATE'S SURCHARGED AND DIFFERENT FORMS OF RETAINING WALLS, AND TURNBULL'S TREATISE ON THE COMPOUND ENGINE.

"The above named works form Nos. 7 and 8 of Van Nostrand's Science Series, several times mentioned in our columns. The value of the treatise on retaining walls is sufficiently guaranteed by the name of the author, who is well known as a very able engineer. The discussion on the subject involves the use of mathematics to such a degree that it will not be comprehensible, except to such as have been mathematically trained. The tables derived from the discussion are, however, of great value for reference. They are five in number. The first gives the thickness of vertical retaining walls, to sustain the pressure of earth, sand, etc., level with its top for different heights of walls. The second table gives the double moments of the pressure of the weight of embankments of earth, sand, etc., level with the top of wall for different heights. The fourth table gives the thickness of vertical retaining walls to sustain the pressure of a surcharged embankment of earth, sand, etc. The fifth table gives the double moments of the pressure of the weight of surcharged embankments of earth, sand, etc. In the treatise on the compound steam engine, the use of mathematics is so far avoided that almost any one familiar with the structure of steam engines may read it understandingly. Theoretical and indicator diagrams are given, which clearly illustrate the subject."—*New York Artisan.*

INTRODUCTION TO THE STUDY OF ORGANIC CHEMISTRY: THE CHEMISTRY OF CARBON AND ITS COMPOUNDS. By HENRY E. ARMSTRONG, Ph. D., F. C. S., Professor of Chemistry in the London Institution. London: Longmans, Green, and Co.

The greatly increased facilities which a sound knowledge of organic chemistry affords for the successful carrying on of many branches of our national industries is now very generally recognized, yet the difficulties usually attending the earlier studies of the subject suffice to prevent a large number of even diligent students from acquiring anything approaching a satisfactory acquaintance with it; henceforth, however, these difficulties will be materially lessened, since from Prof. Armstrong's admirable little volume, just issued as one of the Messrs. Longman's Text Books of Science, so complete an outline of the subject may readily to obtained as will be valuable of itself, and extremely useful for facilitating the profitable reading of the most complete works bearing upon the technology of any particular manufacture. The matter is treated in a thoroughly systematic and scientific manner, yet the style is sufficiently popular for any student of ordinary intelligence to derive advantage from it; he will learn the methods employed in ascertaining the composition of carbon compounds, and of representing them by empirical formulæ, and by formulæ which not only express their composition, but to some extent their nature also. He then proceeds to the consideration of the action of reagents on

carbon compounds, and of the compounds of carbon with oxygen, sulphur, and nitrogen respectively; the remaining families of carbon compounds are then considered in the order of their relation to the hydrocarbons.

The volume is in every respect adapted to the wants of the practical man; it will afford him all the information likely to be useful to him in carrying on his business to the greatest advantage, without troubling him with more theoretical details than are absolutely necessary to enable him thoroughly to comprehend the facts placed before him. In producing such a book Prof Armstrong shows not only that he is himself a master of the subject, but that he possesses great facility for imparting that knowledge to others.

AN ELEMENTARY TREATISE ON STEAM. By JOHN PERRY, B. E. London. For sale by D. Van Nostrand. Price $1.50, cloth.

This little 16mo volume of 400 pages contains more correct information on the subject of Steam Motors than we have found before within so small a space. It is moreover exceedingly well adapted to the use of students, affording numerous well selected problems for practice.

To read it profitably the student must be familiar with simple algebraic equations, the first principles of trigonometry, and the leading facts of elementary physics.

The author has divided the whole work into four parts or books treating respectively of Heat —Steam Engines and Boilers—Locomotives, and Marine Engines. The illustrations, about eighty in number, are distributed through the text.

BUILDING CONSTRUCTION; showing the Employment of Brick, Stone and Slate in the Practical Construction of Buildings. By R. SCOTT BURN. New York: G. P. Putnam's Sons.

This is a recent addition to Putnam's Elementary Science Series.

It is exceedingly rudimentary in plan, but little if anything more being attempted by the author than briefly defining and illustrating the technical terms employed in building.

The book doubtless affords excellent suggestions to the teachers of object lessons in our primary schools. The student who desires to learn something of building is referred to the more advanced books.

Vol. 2d. Plates to the above; giving in a neat form examples on a more liberal scale than those interspersed in the text.

BUILDING CONSTRUCTION, showing the Employment of Timber, Lead and Iron Work in Construction. By R. SCOTT BURN. New York: G. P. Putnam's Sons.

Vol. 1.—Text.

Vol. 2.—Plates.

The chapters into which this brief treatise is divided treat successively of:

Chap. 1st. Drawing—Drawing Instruments—Drawing Scales—Plans, Elevations, and Sections.

Chap. 2d. Timber construction as exemplified in the framing of floors, partitions, and roofs.

Chap. 3d. Timber construction as exemplified in doors, windows, and internal fittings of houses.

Chap. 4th. Work in Lead and Iron.

As in the preceding there are many wood-cuts distributed through the text for its illustration.

The second volume contains twenty neatly executed plates, which seem judiciously selected with reference to affording a good variety of examples.

FUEL. By WM. SIEMENS, D. C. L., F. R. S. To which is appended. THE VALUE OF ARTIFICIAL FUELS AS COMPARED WITH COAL. By JOHN WORMALD, C. E. New York: D. Van Nostrand. Price 50 cts., boards.

This is the latest issue of Van Nostrand's Science Series. Both essays have appeared in the pages of this magazine. They are different from each other inasmuch as the former is a thorough exposition of the laws of combustion and the necessary deductions to be carefully remembered in their application; while the other is of a thoroughly practical kind, and discusses recent experiences with some of the expedients devised to save the cost attendant upon burning coal only.

TABLEAUX COMPARATIFS DES MESURES, POIDS ET MONAIES. Par HERCULE CAVALLI. Paris: Libraire Administrative de Paul Dupont. For sale by D. Van Nostrand.

This collection of tables seems to be altogether indispensable to the reader of history as well as to the student of art or science.

The weights, measures and coins of all countries and all times are compared with the English and French standards.

We have rarely seen a work containing tables only which was designed to satisfy a want of so many classes of readers.

ETUDES SUR LES CONSTRUCTIONS A LA MER. Par M. BONNICEAU. Paris: Lacroix. For sale by Van Nostrand. Price $7.20, cloth.

This compact little work affords an insight into the engineering methods employed in the improvement of harbors, in many parts of the world, and in both modern and ancient times

Wharves, Docks, Jetties, Bridges and Lighthouses are all treated in turn and all abundantly illustrated in the accompanying volume of plates.

AN ELEMENTARY TREATISE ON QUATERNIONS. By P. G. TAIT, M. A. Second edition. Oxford: Clarendon Press. For Sale by D. Van Nostrand.

Mathematical students or students of applied science who hope to continue their labor with profit for another decade, must evidently read up on Quaternions.

The signs are abundant that this department of mathematics is rapidly being employed effectively in investigations of physical laws.

The first edition of this elegant work was widely sold in this country; a fact which the author gratefully acknowledges in the preface to the present edition.

The author's renown is such that we need not attest the thoroughness or clearness of the treatise.

DICTIONARY OF ELEVATIONS AND CLIMATIC REGISTER OF THE UNITED STATES. By J. M. TONER, M. D. New York: D. Van Nostrand. Price $3.50 cloth.

This work contains in addition to elevations, the latitude, mean annual temperature, and the total annual rain-fall of all the cities, towns and localities in the United States, concerning which the requisite data have been obtainable. The orographic

and other physical peculiarities of North America and more briefly of the world, have also been noted with the care and industry for which the author is distinguished, and altogether the work supplies an amount and kind of information that makes it unique in the field occupied. The work, he says, has been undertaken chiefly for the purpose of placing within reach of the medical profession a record that may enable and induce professional men in different localities to observe, record, and contrast the influence of elevation, if it has any, on health and disease. Hitherto latitude and longitude have been the chief and almost the only conditions modifying climate, that have been taken into account in considering the influences of localities on health; but the observations of physicians and travellers present facts suggesting that altitude to some extent controls the type of diseases. Of course it is necessary for the observer to keep in view the influences not only of latitude and longitude, but also of a dry or a humid atmosphere, and of a high or a low barometer. The Dictionary points out convenient modes of taking observations by those feeling an interest in the subject. Heights of localities may be determined approximately with the aid of a barometer, as the mercury falls in it about 1 in. for every 940 ft. of elevation above the level of the sea; or by boiling water, which at sea level boils at 212 deg., but owing to the lessened weight of atmosphere in ascending, boils at the rate of 1 deg. less for every 450 ft. of perpendicular ascent. The thermometer, too, registers in almost any locality 1 deg. lower temperature for about 300 ft. of perpendicular height above the level of the sea. These conditions or laws of the ocean of atmosphere in which we live, and which has a depth estimated at 45 miles, and weight of 15 lbs. to the sq. in., are nearly constant, and with the well-known purity of the free circulating air and the great abundance of electricity and ozone, which constantly pervades elevated localities, are elements too potent not to exercise an important influence on man's well being. All the data obtainable, points to the fact that a residence in a moderately elevated region, either in the tropical or temperate zone, anywhere between a few hundred feet above the level of the sea, and a line that marks Alpine vegetation, is healthier that the tide-water lands. It is in this intermediate strata of climatic and barometric influence that the human race attains its noblest physical development. The most productive States of our Union, with the largest population and with the greatest aggregate wealth, are to be found among those having an average elevation above the sea of from 400 to 1,000 ft. The pursuits of commerce have, however, caused most of our large cities to be placed on low ground, near navigable waters. The table of 311 towns in this Dictionary shows that the majority of the denizens of our large American cities are living at an elevation of but a few hundred feet above tide water; and that there are eighty cities situated at an elevation of less than 100 ft. above sea level, with a combined population of 4,868,107. It does not appear that the site of a single city in the United States has been selected because of the special salubrity of the locality. In a hygienic sense it is to be regretted that the larger commercial cities do not occupy more elevated sites. There is a noticeable peculiarity in the location of our American cities, at or near the mouth of rivers emptying into the Atlantic ocean, in the fact that they are all situated on the left bank; and, further, there is scarcely an exception to the fact that to the south of all these cities there are large marshy flats, over which the prevailing winds blow, and carry the miasm directly across the cities.—*Washington Star.*

MISCELLANEOUS.

PETER COOPER.—This venerable philanthropist has just entered upon the 84th year of his useful and honorable life, and in recognition of his exalted character and many public services, a birthday reception was given him on the 12th inst. by a number of our most distinguished citizens, all of whom joined in expressing their esteem for him. We quote the following eloquent passages from his remarks in reply to the address of congratulation delivered on that occasion:

"Measured by the achievements of the years I have seen, I am one of the oldest men who have ever lived; but I do not feel old, and I propose to give the receipt by which I have preserved my youth. I have always given a friendly welcome to new ideas, and I have endeavored not to feel too old to learn—and, thus, though I stand here with the snows of so many winters upon my head, my faith in human nature, my belief in the progress of man to a better social condition, and especially my trust in the ability of men to establish and maintain self-government, are as fresh and as young as when I began to travel the path of life. While I have always recognized that the object of business is to make money in an honorable manner, I have endeavored to remember that the object of life is to do good. Hence I have been ready to engage in all new enterprises, and, without incurring debt, to risk the means which I had acquired, in their promotion, provided they seemed to me calculated to advance the general good. This will account for my early attempt to perfect the steam engine, for my early attempt to construct the first American locomotive, for my connection with the telegraph in a course of efforts to unite our country with the European world, and for my recent efforts to solve the problem of economical steam navigation on the canals; to all of which you have so kindly referred. It happens to but few men to change the current of human progress, as it did to Watt, to Fulton, to Stephenson, and to Morse; but most men may be ready to welcome laborers to a new field of usefulness, and to clear the road for their progress.

"This I have tried to do, as well in the perfecting and execution of their ideas, as in making such provisions as my means have permitted for the proper education of the young mechanics and citizens of my native city; in order to fit them for the reception of new ideas, social, mechanical, and scientific; hoping thus to economize and expand the intellectual as well as the physical forces and provide a larger fund for distribution among the various classes which necessarily make up the total of society.

"I feel that nature has provided bountifully for the wants of all men, and that we need only knowledge, scientific, political, and religious, and self-control, in order to eradicate the evils under which

society has suffered in all ages. Let me say, then, in conclusion, that my experience of life has not dimmed my hopes for humanity; that my sun is not setting in clouds and darkness; but is going down cheerfully in a clear firmament lighted up by the glory of God, who should always be venerated and loved as the infinite source and foundation of all light—life—power—wisdom and goodness."

NOTES ON MAGNETISM.—M Gaugain.—A singular fact is stated. If a bar of iron is magnetized as strongly as is possible with a current of determinate intensity, one may increase its magnetization by employing currents with the same direction, but of less intensity. Thus having magnetized a horse-shoe bar to the maximum obtainable with a current of intensity 39,594, the current of detachment obtained under the influence of the constant magnetism was 45. Then M. Gaugain re-commenced the magnetization, using, successively, currents with the intensities 16060, 12069, 6993, and 5161; and the values of the corresponding currents of detachment were 49.8, 52.9, 56.5, and 57.9. He then tried again the current used first, and the current of detachment fell to 45. Thus, the magnetization developed by a weak current is destroyed by a more energetic current in the same direction. But this curious fact and that mentioned in paragraph 52 (see "Telegraphic Journal," page 21), depend on the mode of detaching the armature. This, in the cases described, was by a sudden movement in a direction perpendicular to the polar faces; if it is detached by making it glide parallel to these faces, the results are different. Using the process of magnetization described in paragraph 52, the maximum value of constant magnetism is greater than in the case where the armature is detached by a sudden movement; and in the case just described, successive weaker currents did not increase the magnetization. M. Gaugain thinks it certain that the detachment of the armature always weakens the magnetism, and that it is by causing a shaking (*ebranlement*) among the iron molecules, which diminishes the coercitive force. He thus explains the phenomena described in paragraph 52: According to Ampère's views, magnetization consists in a certain orientation of molecules, or of currents which circulate about them; and, since the persistent magnetization of iron is very different from the magnetization it acquires from an inducing current, we must suppose that the molecules which remain directed (*orientées*) after the interruption of the inducing current and the detachment of the armature, are, from their nature and position, endowed with a greater coercitive force than the other molecules. Now when one performs, for the second time, the series of operations in paragraph 52, it is evident that the molecules preserving their orientation after detachments of the armature of the first series, will not be deranged by the renewal of the inducing current; and they will, naturally, be more apt than others to resist the shaking caused by new detachments of the armature. On the other hand, among the molecules on which the current impresses a movement of rotation, there will be new ones which will possess this coercitive force necessary for the orientation to become persistent. We can thus conceive that the number of molecules directed in a permanent manner may be greater after the second series of operations than after the first, although the detachment of the armature has always the effect of diminishing the permanent magnetism; each new series of operations has the effect of establishing a sort of selection among the molecules, and bringing to magnetic orientation those which possess the greatest coercitive force. The magnetization ceases to increase when all the molecules gifted with this superior coercitive force have received the magnetic orientation. Next, as to the effects stated in the beginning of this note. When the current 39594 has acted, and the magnetization has been raised to its maximum, we must suppose that there is no longer, in the annular space influenced by this current, any molecule to direct, among those possessing coercitive force sufficient to resist the detachment of the armature. But it is natural to suppose that the molecular shaking, which results from this detachment, is more violent the stronger the armature is held, the more intense the inducing current; and we may conceive that the molecules which have not a sufficient coercitive force to resist the detachment of the armature which followed the passage of the current 39594 can nevertheless retain their orientation when the armature is detached after passage of a weaker current. This being allowed, we can readily understand how a weaker current may reinforce the magnetization developed by a stronger current; the molecules which the former brings to magnetic orientation will be equally brought to it by the latter; but they preserve their orientation when the weaker of the two currents is employed, and do not preserve it with the stronger current; because the shaking which results from detachment of the armature is less violent in the first case than in the second. The increase of magnetization obtained when the armature is detached by sliding along, instead of sudden detachment, is explained by the consideration that the molecular shaking must be less violent in the former case than in the latter.

A REMARKABLE PUMPING ENGINE.—The last number of the "Journal of the Franklin Institute" contains the report of the trial of the new Worthington duplex pumping engine, at Phœnixville, Pa. This is a compound duplex of a new type, having but one high-pressure and one low-pressure cylinder, instead of two of each kind. Of the two pumps, one is worked by a high-pressure cylinder, exhausting into a tank, and the other by a low-pressure cylinder, receiving steam from the tank. There is no expansion in either cylinder. The high-pressure pump-plunger is 12 in., with a piston-rod 2½ in. in diameter; the low-pressure plunger is 14 in., with a piston-rod 3 in. in diameter; the stroke is 2 ft., and the capacity 54.24 galls. per revolution of both pumps—the term revolution being employed to signify a complete double stroke, or what would require a revolution if the engine had a crank. It will be seen that the dimensions given are so small as not to be ordinarily associated in practice with the highest degree of economy. The contract made with Mr. Worthington demanded a capacity of 1,000,000 galls., lifted 182.79 ft. in 24 hours, and a duty of 45,000,000 foot-pounds per 100 lbs. of coal. On the trial the pumps actually raised in six hours an amount of water representing 1,626,436 gallons in

24 hours, and achieved the duty of 68,620,360 foot-pounds, without any allowance for friction in the pipes. The committee adds in its report that Mr. Worthington is fairly entitled to add 2 ft. to the actual height pumped, which will give him an actual duty of 70,422,306 foot-pounds. This extraordinary performance will attract much attention from engineers. We need only say, with regard to it, that the trial-report shows no evidences of forcing the figures to obtain this result, and that the little pump which thus challenges the Cornish engine itself, is compact and cheap, as well as efficient.

JARRE'S POWER PUMP.—A year or two since there was some talk of the hydro-pneumatic pump of M. Jarre, for the transmission of power to a considerable distance; M. Haton has now made a report upon it to the Société d'Encouragement of Paris.

The problem of transmitting power over long distances full of obstacles is undoubtedly not an easy one, and M. Jarre avails himself of compressed air for the purpose, and acts directly on the water without the aid of a piston. The pressure in the air conduit being subject to little variation, and resulting from the action of the force-pump, which is placed at a long distance from the source to be drawn from, a special arrangement was necessary to work the valves of injection and emission.

M. Jarre has adopted an intermittent fountain. An oscillating beam alternately opens and closes the way through which the compressed air finds its way to the surface of the water to be raised, according to the variations of weight in two movable parts of the apparatus, when in air and when immersed in water, that is to say, when the level of the water rises or falls. The action of the compressed air thus follows closely the movement of the water, and the pump continues its action so long as the pressure of the air is sufficient.

Several pumps of this kind have worked with success for two years at the Ornans Works, of which M. Jarre is directing engineer. It is admitted that there is a disadvantage in causing the air to act directly on the water, because the effective pressure is thus limited to the fixed pressure of the ascending column of the liquid, and by any loss in the conduits; but this objection is compensated by the special advantages of the pump in certain cases. Thus, one of them is placed at the distance of nearly 500 feet from the motor, and the compressed air reaches it through a tube only four-fifths of an inch in diameter, and having twenty-eight heads at right angles. The water raised, which amounts to eighteen gallons per minute. is conducted through a pipe of 1¾ inches in diameter, with nine right angle bends, and two stopcocks.

INCRUSTATION IN BOILERS.—Messieurs Champion and Pellet have made a communication to the Society of Civil Engineers of Paris on the important subject of incrustation in boilers.

The authors say the most certain mode of avoiding deposits and incrustations is to separate the calcareous salts from the water before its introduction in the boiler; and incrustation they declare is caused principally by the water containing both sulphate and bicarbonate of lime. In this case barytes, a or mixture of soda and lime, may be used with success. The authors occupy themselves especially with the deposits formed by the decomposition of the bicarbonate of lime under the influence of heat, and which causes such freqent accidents. The carbonate, acted upon by an excess of carbonic acid, takes with it. in precipitating, small quantities of greasy matter contained in the water, and the pulverulent deposit thus formed prevents the contact of the water with the sides of the boiler.

The mode proposed for preventing this, lately adopted on the Northern Railway of France, consists in the addition of milk of lime corresponding in quantity with the excess of carbonic acid. This system, however, which answered perfectly at some sugar works at the end of one season, was found inefficient in the following year; and MM. Champion and Pellet instituted further experiments, and state that when lime-water is introduced into water containing a certain amount of calcareous bi-carbonate, so as to saturate the excess of carbonic and, a flocculent precipitate of carbonate of lime is quickly formed; and if the water is left quiet for a few hours, and filtered, it is then exempt from lime; if, on the contrary, the carbonate is less in quantity, no precipitation is formed, even by agitation after many hours. In this latter case, MM. Champion and Pellet have found that the carbonate is in a condition of supersaturation, and possesses a considerable amount of solubility. This property alone, however, is not considered sufficient to account for the failure in question.

Comparing results, it appears likely that the non-precipitable carbonate might be removed by the formation in the water of an abundant precipitate of carbonate of lime, obtained by means of a soluble salt of lime, and such proved to be the case. It was found, morover, that the addition of certain pulverulent substances, such as silica, lime, or natural sand in fine powder, produced a like effect. It appears, therefore, that the presence of a precipitate, even of a foreign nature, causes a sort of disassociation between the water and the carbonate of lime, and the precipitation of the latter. The failure already referred to must have arisen from a variation in amount of carbonic acid in the water, and consequently in the proportion of carbonate of lime dissolved; it is evident, therefore, that it is necessary to ascertain the amount of the carbonate of lime and the excess of carbonic acid in the water. In effect this excess furnishes, in contact with the lime, a new quantity of carbonate, which, added to the first, may cause precipitation.

From the above experiments and facts, MM. Champion and Pellet deduce the following general method of treating water, in which the proportion of lime is not sufficient to cause precipitation. It is sufficient, they say, to add a few thousandth parts of pulverized limestone to water already saturated by the proportion of lime corresponding with the excess of carbonic acid, but it is preferable to use carbonate of soda instead of lime, an excess of which would give rise to accidents, which we desire to avoid. Even oxalate of ammonia, active test as it is, will not show a trace of lime in water thus treated. After some hours' repose, the greater part of the carbonate is deposited, and what remains in suspension may be removed by filtration.